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DEVELOPMENT OF THE FULL SCALE T63 TEST FOR SPECIFICATION MIL-L---ETC(U)
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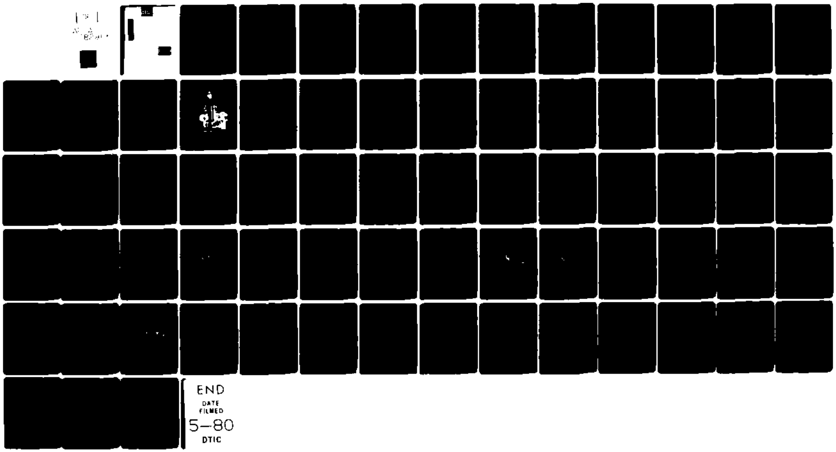

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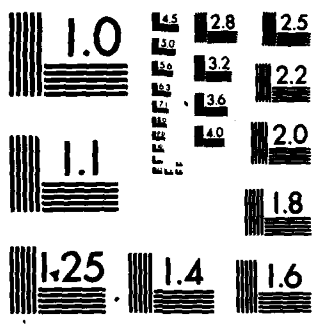

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The T56 engine had been utilized for the full scale engine test required under the qualification process for lubricants Specifications MIL-L-23699 and XAS-2354. As advanced engine operating environments became more severe, and the quality of new lubricants improved, the T56 engine became marginal in its ability to thoroughly test gas turbine lubricants. As a result, a new engine was selected through an evaluation of engines in service. The T63-A-5A engine was chosen because of its present level of severity on the

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turbine section lube wetted parts and its potential for increased severity testing through engine/lube system modification.

This report presents the results of engine modifications and operating procedures developed in establishing the T63 engine test for gas turbine lube oil qualification.

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PROPULSION TECHNOLOGY AND PROJECT ENGINEERING DEPARTMENT

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DEVELOPMENT OF THE FULL SCALE T63 TEST FOR SPECIFICATION MIL-L-23699 AND XAS-2354 GAS TURBINE LUBRICANTS

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CONVERSION FACTORS: SI TO U.S. CUSTOMARY UNITS

Parameter	To Convert From SI Units	To U.S. Customary Units	Multiply by
Temperature	Degrees Celsius (°C)	Degrees Fahrenheit (°F)	Use Equation 1
Power	Watts (W)	Shaft Horsepower (SHP)	1.341×10^{-3}
Viscosity	Meters^2/sec.	Centistokes	1×10^{6}

Equation 1: $t_f = 9/5\ (t_c) + 32$ where,
t_f = degrees Fahrenheit
t_c = degrees Celsius

LIST OF FIGURES

INTRODUCTION

Projections for the future generation of gas turbine engines show that lubricants will be expected to perform at higher temperatures, resist decomposition on hotter surfaces, and have more load carrying capability than the present MIL-L-23699 lubricants used in Naval aircraft engines. An advanced lubricant specification, XAS-2354, was established to introduce the lubricants having improved characteristics.

Previously the T56-A-7 turboprop engine had been used as the full scale engine test vehicle for the qualification of lubricants under Specification MIL-L-23699. Since the XAS-2354 specification extends the capabilities of gas turbine lubricants to the more severe environments found in advanced engines, it was necessary to modify the engine and test conditions to simulate these more severe engine operating parameters. Experience gained by virtue of several tests proved the T56 engine marginal in its ability to achieve the desired conditions.

The cost of operating the T56 engine was also becoming excessive. The soaring fuel costs associated with running this type of large engine for lubricant testing made continued operation uneconomical. Also, parts for the older T56-A-7A model were becoming scarce. At that time a study was undertaken to select a different engine for lubricant qualification testing.

Economic and maintenance considerations led to the conclusion that a small turboshaft engine with "hot" bearing compartments would be most desirable for assessing lubricant deposition and deterioration characteristics. Inspection of two T63 engines run at Detroit Diesel Allison Division (DDAD) (references 1 and 2) showed that this engine had the operating characteristics to meet at least the lubricant deposition criteria.

Although the T56 engine was satisfactory for qualification evaluation of MIL-L-23699 lubricants, it was determined that it was not practical to have two separate engine tests, one for each specification. Therefore, the overall consideration was to develop one engine test for both the XAS-2354 and MIL-L-23699 lubricant specifications.

References 3 and 4 authorized the Naval Air Propulsion Center (NAPC) to develop a full scale T63-A-5A engine test for Specifications XAS-2354 and MIL-L-23699 lubricants. This report discusses the results of the program and completes the work authorized by reference 4.

CONCLUSIONS

1. The T63-A-5A engine oil qualification test performed in accordance with Appendix A, will subject the lubricant to engine environments that are:

   a. capable of establishing the lubricants deposit characteristics

b. sufficiently reproducible to allow differentation of deposit forming characteristics among candidate lubricants

c. inadequate regarding severity on bulk oil stability.

2. The severity of conditions affecting bulk oil stability cannot be increased practically without introducing unrealistic methods of controlling and varying lubricant temperature.

3. The oil deposition performance established in the Phase III engine tests (Appendices D, E and F) is acceptable as baseline criteria in rating the performance of candidate oils for specifications MIL-L-23699 and XAS-2354.

RECOMMENDATIONS

1. The T63-A-5A engine lubricant test should be conducted per Appendix A to meet the engine test requirements for specifications MIL-L-23699 and XAS-2354.

2. The lubricant deposit formations as described in Appendices D, E and F and as documented by photographs on file at NAPC, should be adopted as the baseline reference to evaluate the deposition characteristics of candidate lubricants. For MIL-L-23699C candidates, the deposit formations should be at least equivalent to the baseline reference. For XAS-2354A candidates the deposit formations should be significantly less than those of the baseline reference.

3. The bulk oil stability criteria for candidate oils should be based primarily on the results of the Oxidation/Corrosion tests and the Erdco Bearing test of the oil specifications.

DESCRIPTION

Engine

1. The T63-A-5A turboshaft engine shown in Figure 1, is manufactured by DDAD. It is an internal combustion-gas turbine engine featuring a "free" power turbine. The engine consists of a combination axial-centrifugal compressor, a single "can" type combustor, a turbine assembly consisting of a two-stage gas producer turbine, a two-stage power turbine and an exhaust collector. The gearbox contains the gas producer and power turbine gear trains. The gearbox housing is the engine's principal structural member. It supports both the compressor and the turbine assemblies and incorporates the engine's only mounting points.

2. The engine is 102.48 cm (40.35 inches) in length and its weight without accessories is 61.81 kg (136 pounds). At maximum power it is rated at 236.38 x 10^3 watts (317 shaft horsepower).

3. The engine is instrumented with various temperature and pressure probes located throughout the engine. These probes are monitored and control

hardware is adjusted as needed to provide similar conditions for each engine test.

4. The T63-A-5A engine lubrication system configuration allows the oil flow to be divided downstream of the pressure regulator assembly, as seen in Figure 2. Eighty-six percent of the oil flow is delivered at a controlled temperature to the number 1 through 5 bearings and the gearbox section of the engine. The remaining fourteen percent of the flow is put through an oil bath immersion heater and elevated to a "hot" controlled temperature for bearings 6, 7 and 8 in the turbine section. A four bank scavenge pump returns the lubricant to the oil tank.

Test Cell

The engine is installed in a sea level test cell utilizing a conventional three point mounting system per reference 5. The power output shaft is connected to a flywheel which is coupled to a waterbrake to absorb the power generated by the engine. The entire test stand is portable with all assemblies and associated shafting permanently aligned for easy installation.

Lubricant Evaluation

To determine the acceptability of a lubricant in the full scale test, two items are considered. First, the lubricant is checked periodically during the test to detect if there is any change in viscosity, total acid number, or contamination. Any significant changes in these values are indicators of degradation of the lubricant. Secondly, after the test is completed and the engine is disassembled, the oil wetted parts are individually examined and evaluated in regard to the amount and nature of deposition on the parts.

Test Lubricants

All lubricants used in the T63-A-5A oil qualification engine test development program were MIL-L-23699B type lubricants.

DISCUSSION AND ANALYSIS OF RESULTS

1. In the T56 engine lubricating oil qualification testing under specification XAS-2354, operating conditions had been stretched to the engine's limit. In adopting the T63-A-5A engine, the aim was to achieve, without over-extending the engine's capabilities, a level of severity that would allow degradation of the lubricant and deposition on engine parts to an extent permitting classification of lubricant characteristics.

2. The development of the T63-A-5A engine test occurred in three phases. The first phase was conducted to become familiar with the engine operating characteristics and resulting lubricant degradation/definition. The second phase produced a test cycle, defined the necessary engine hardware modifications and initiated bearing temperature measurements. The final phase defined the test duration and established the baseline engine test performance.

a. Phase I Engine Testing

(1) Testing in this phase of the program was conducted primarily to familiarize personnel with the engine, its instrumentation, installation and operating procedures. A Test Directive, reference 6, was drafted, proposing a 120-hour endurance period consisting of 40-three hour cycles. Each cycle consisted of various power settings as seen in Figure 3. The cycle was felt to have power settings and duration time representing a conceivable duty cycle for this engine.

(2) The first problem that occurred during testing was high turbine section vibrations. At disassembly and inspection, it was revealed that the cage of the number 7 bearing had failed and also that the number 8 bearing outer race was rotating in its housing. This rotation of the number 8 bearing outer race was typical of the T63-A-5A model and was corrected by using a T63-A-700 style bearing retaining plate. Appendix B gives details of this modification.

(3) Following the incorporation of this fix into a second engine, testing was continued to acquire operation experience with the engine and test cell. It also provided a direction for test development with respect to desired lubricant degradation. Inspection of the disassembled engine at the completion of test showed the compressor and gearbox area oil wetted parts to have only light tan varnish with the turbine section exhibiting only medium to heavy brown varnish.

(4) The results of the engine inspection were discouraging in light of the in-service inspections of T63 engines. In addition to low deposition levels, oil sampling showed little change in the lubricant's bulk oil properties. A review of the test procedure was conducted and two ideas to increase the severity of the test resulted. First, the oil system capacity was reduced from 12 quarts to 6 quarts, resulting in an increased re-cycle time for the oil, and secondly, the cycle itself was modified to attempt to increase oil degradation and deposition.

b. Phase II Engine Testing

(1) A newly overhauled engine was installed and run solely to gather data to develop a new test cycle. The engine for this test had three thermocouples installed to measure oil-wetted surface temperatures in the turbine section. These were located on the housings of the numbers 7 and 8 bearings. Thermocouple installation details are described in Appendix C as well as the significance of the temperature measurements.

(2) Initial testing was performed at Normal Rated Power (NRP) with a constant engine oil pump-in temperature while the oil temperature to the turbine section was varied. Bearing housing temperatures in the numbers 7 and 8 bearing compartments were recorded and plotted against the varying hot section oil-in temperatures. These plots are shown in Figures 4 and 5.

(3) Originally, it was desired to operate the test with hot section oil-in temperatures that would result in oil-wetted bearing housing surface temperatures of approximately 232°C (450°F). This high surface temperature would be ideal for testing the deposition characteristics of the lubricants. However, after reviewing the data from this test, it was realized that the desired temperature was unattainable. By extrapolating the graphs in Figures 4 and 5 it was found that in order to achieve the surface temperatures desired it would be necessary to operate with a hot section oil-in temperature far in excess of the engine's limitation. A hot section oil-in temperature of 148.8°C (300°F) was selected for the test which permitted maximum bearing surface temperatures of approximately 193°C (390°F) for the NRP condition

(4) Additional testing was performed with a constant hot section oil-in temperature while the engine power setting was varied. This produced data of bearing surface temperatures versus Turbine Outlet Temperature (TOT), as shown in Figure 6. As expected surface temperatures increased as power setting increased. However, even at the maximum TOT permitted, the desired oil-wetted bearing surface temperature, 232°C (450°F), could not be achieved.

(5) The final testing with this engine investigated the shutdown portion of test operation. Standard procedure is to run at ground idle for two minutes before shutdown, thus allowing the engine to cool. At shutdown the oil flow which lubricates and cools internal surfaces ceases. Residual heat within the turbine section causes the temperatures of the hot section bearing to rise, reach peak values and then gradually decrease. This segment of shutdown is defined as the soakback condition. A shutdown procedure which would produce hot soakback conditions would create a severe environment in regard to the lubricant's deposition characteristics.

(6) Bearing temperatures were recorded after shutting down the engine under three different conditions. The variable at this point consisted of changing the amount of time the engine was run at ground idle before being chopped. The intervals selected were 15, 30 and 60 seconds. In all three cases, prior to reducing the power to ground idle, the engine was run at maximum power for five minutes with a constant oil-in temperature. The data from the soakback investigation is presented in Figures 7 and 8 and as expected, the maximum temperatures occurred for the 15 second condition.

(7) The data collected during these tests were reviewed and conditions selected that would provide the best environment to test the lubricants deposition characteristics. The new test cycle was to include the most severe conditions experienced. To achieve maximum severity the cycle would have to run with a 149°C (300°F) hot section oil-in temperature, operate predominantly at the maximum continuous power setting allowed by the manufacturer and utilize the 15 seconds at ground idle shutdown method. Since the high temperatures experienced during the soakback portion of the test were essential for establishing deposition characteristics, an adequate time interval between cycles was also considered necessary in designing the test schedule. Further, to insure repeatable operation, a warm-up period was required to permit the lubricant to reach the specified test conditions. With these considerations the Figure 9 test cycle was developed. Four 1.5 hour cycles could be run in

one eight hour period with a 0.5 hour interval between the end of one and the beginning of another cycle.

(8) Using a newly overhauled engine, a test was initiated using the new test cycle. At 27 hours the test was interrupted and the combustion section was removed to permit access to the number 8 bearing compartment. Inspection of this area was encouraging because lube degradation deposits were beginning to form. However, it was noticed that the retaining plate (Figure 10) installed to prevent rotation of the number 8 bearing outer race was shielding the lubricant from exposure to the hot walls within the machined recesses of the bearing housing. To allow access of the lubricant to these areas the retaining plate was modified (Figure 11) by drilling seven holes to coincide with the recessed pockets in the housing.

(9) Notes were made on the condition of the number 8 bearing compartment and the engine was reassembled. Problems experienced in scheduling four cycles during an eight hour period were resolved by shortening each cycle by ten minutes. This change produced the "Finalized Test Cycle", which is shown in Figure 12.

(10) Testing was then continued to evaluate the effects of the changed cycle and retaining plate modification. After an additional 32 hours of testing, the number 8 bearing compartment was opened for inspection. Deposition levels had increased noticeably over those displayed after the initial 27 hours of testing. Closer examination of the recessed areas within the bearing housing showed that some portions were still not being exposed to the oil. A second modification, shown in Figure 13, was made to the retaining plate which joined the drilled holes together forming three curved slots. This change provided maximum exposure of the lubricant to the recessed walls of the bearing compartment.

c. Phase III Engine Tests

(1) The final phase of test development consisted of defining the test duration and determining its effectiveness with respect to deposition levels and bulk oil degradation.

(2) A newly overhauled engine was installed and testing conducted in accordance with Appendix A, except that the test duration selected was 113 cycles. The oil selected for this test was considered to be typical in performance of qualified MIL-L-23699 lubricants. After 120 hours of operation, the number 8 bearing compartment was opened revealing substantial deposit formations. Chemical analysis of used oil showed a slight increase in viscosity and total acid number, as seen in Figure 14, and it appeared that the lubricant was continuing to degrade. However, after an additional 30 hours of operation, viscosity and total acid number values showed little change and the test was terminated after 150 hours. The engine was disassembled and the results of the inspection are given in Appendix D.

(3) Review of the information gathered in this test indicated the test severity and duration were adequate to produce substantial deposit formations. However, it was still desirable to produce more lubricant

degradation which would be evidenced by greater changes in viscosity and total acid number of the used oil samples.

(4) Another newly overhauled engine was installed using the same lubricating oil as in the previous test. The test conditions were as stated in Appendix A. After 150 hours of testing, the number 8 bearing compartment was inspected. Deposit levels in the number 8 area were similar to those in the previous test after it had completed 150 hours. Analysis of the lubricating oil, Figure 15, showed a slight increase in viscosity and contamination while the total acid number remained relatively unchanged. At this point it was believed the lubricant was continuing to degrade and that an additional 25 hours of testing would produce the desired degradation results. Deposits in the number 8 compartment were noted, the engine reassembled and the testing continued. After the additional 25 hours were run, the number 8 bearing compartment was again inspected. Comparison to previous notes revealed no great amount of deposit increase in this area. The test was terminated after oil analysis revealed no further significant changes in either viscosity of total acid number. The engine was then removed from the test cell and disassembled. Results of the inspection are given in Appendix E.

(5) At the completion of this test a review of this portion of Phase III engine testing was made. Deposition levels in both tests were reasonable for qualified MIL-L-23699 lubricants; however, the changes in bulk oil characteristics were not as great as desired. The test duration was originally 120 hours. It was increased to 150 hours and finally extended to 175 hours. Prior to each extension in test time it appeared that the lubricant was continuing to degrade its bulk oil characteristics. However, after each time extension was initiated, the apparent increasing trend leveled off or dropped. The process of slowly adding hours to the test while monitoring the resulting deposition levels led to the conclusion that the T63 engine, run under the conditions in Appendix A, was adequate to produce significant deposits in the turbine section but was incapable of causing bulk lubricant breakdown. Its inability to cause significant bulk lubricant degradation was attributed to the fact that only 14 percent of the oil flow is delivered to the severe environment of the turbine section. The remaining 86 percent of the flow was held at a relatively cool temperature of 121°C (250°F) and was delivered to lightly loaded areas and experienced lower temperatures than those in the hot section. These mild conditions for the bulk of the oil would not produce the desired level of degradation of the lubricant. It was decided that in order to achieve meaningful bulk oil degradation using the established test cycle, it would be necessary to run an unrealistic number of cycles or introduce additional test complexity to cause lubricant breakdown. The most practical way to increase degradation would be to elevate the mean bulk oil temperature considerably above 121°C (250°F) by means of an external heater. Due to design temperature limitations in the lube system this would require a test set up including a heating medium to elevate the oil tank temperature, a cooler to lower it back to the maximum permissable engine oil-in temperature and then another heating medium to elevate the turbine section oil up to 149°C (300°F). Use of this method to produce oil degradation would result in an installation that would resemble a test rig more than a full scale engine test. Since the test was already established as being adequately capable

of evaluating the deposition characteristics of lubricants, it was decided that adding an additional heating medium to cause degradation was not practical. Therefore, the stipulation that the engine test provide such degradation was removed from the test requirement. The oxidation/corrosion and Erdco Bearing tests of the oil specification would be relied upon to establish the bulk oil degradation characteristics.

(6) Since the amount of turbine section deposits in these two engine tests was determined to be of an acceptable level to allow comparison of lubricant deposition characteristics, Appendix A was accepted as the Test Directive for the engine test requirement of the lubricating oil qualification program.

(7) Another test was run for 175-hours on a different qualified MIL-L-23699 lubricant under the requirements of Appendix A. This engine utilized positively sealing thermocouple probes in the turbine section per Appendix C, to insure against possible hot gas leakage into the bearing compartments. As in previous T63-A-5A tests, there was no significant increase in oil contamination, viscosity or total acid number, as shown in Figure 16. Deposition levels in this test were somewhat lower than those in the previous tests and are described in the engine inspection report given in Appendix F.

(8) During the tests conducted in phase III, the bearing temperatures were monitored. A typical profile of the number 8 bearing temperature during the operating and soakback cycles is shown on Figure 17. The increase in temperature severity during the soakback cycle is obvious. In Figures 18 and 19, typical data for the numbers 7 and 8 bearing soakback temperatures are plotted for each of the phase III engine tests which show reasonable repeatability of the maximum soakback temperatures.

(9) This third phase of engine test development established that the T63 engine test, when conducted in accordance with the procedure described in Appendix A, gave good repeatability based on the two tests conducted with the same test oil. It also established that when testing two different MIL-L-23699 oils, the test results (engine deposition level) were sufficiently in agreement to represent the level of performance anticipated for such oils.

FIGURE 1: ALLISON T-63 TURBO SHAFT ENGINE

MAJOR ASSEMBLIES

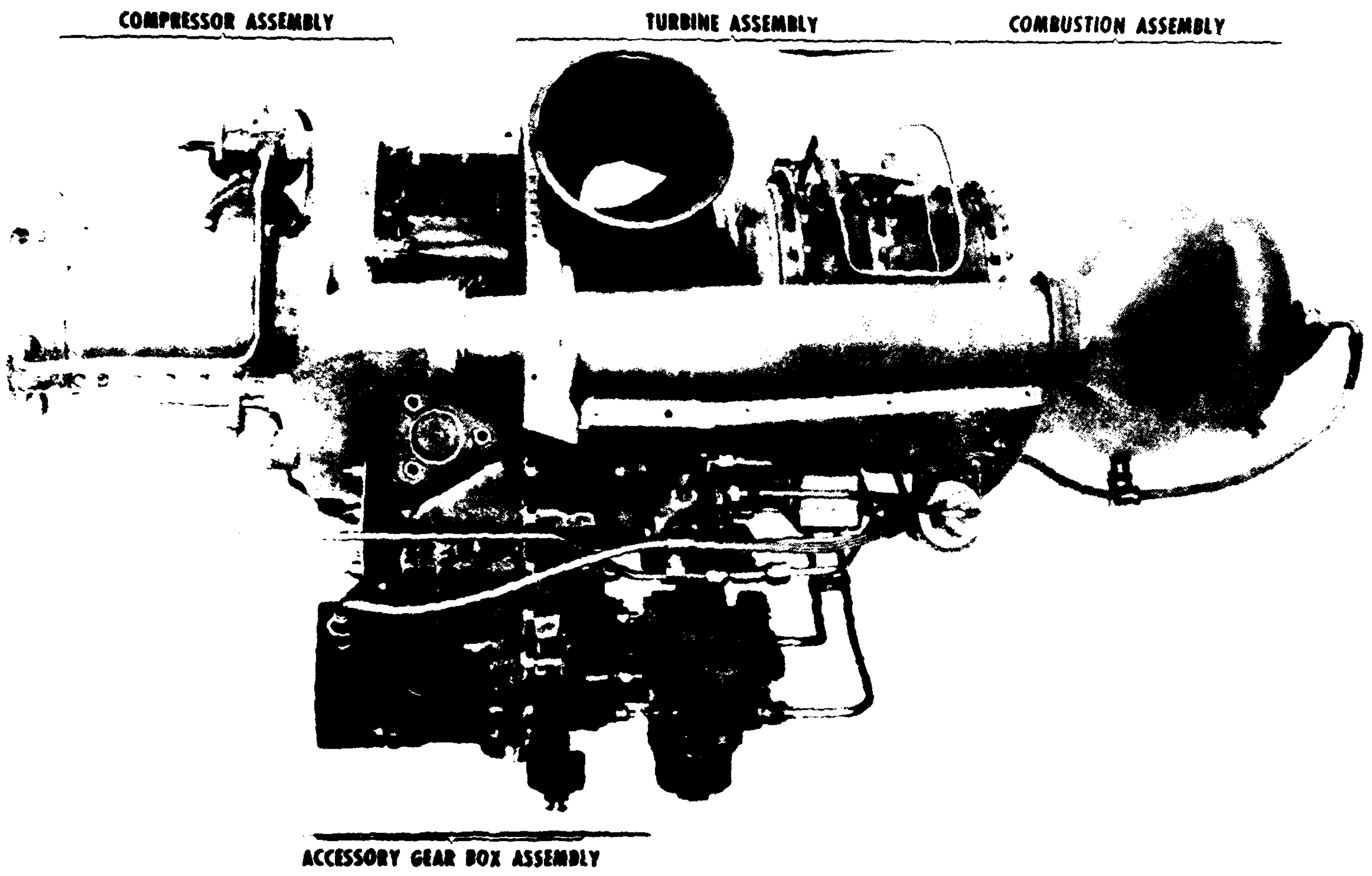


FIGURE 2: LUBRICATION SYSTEM

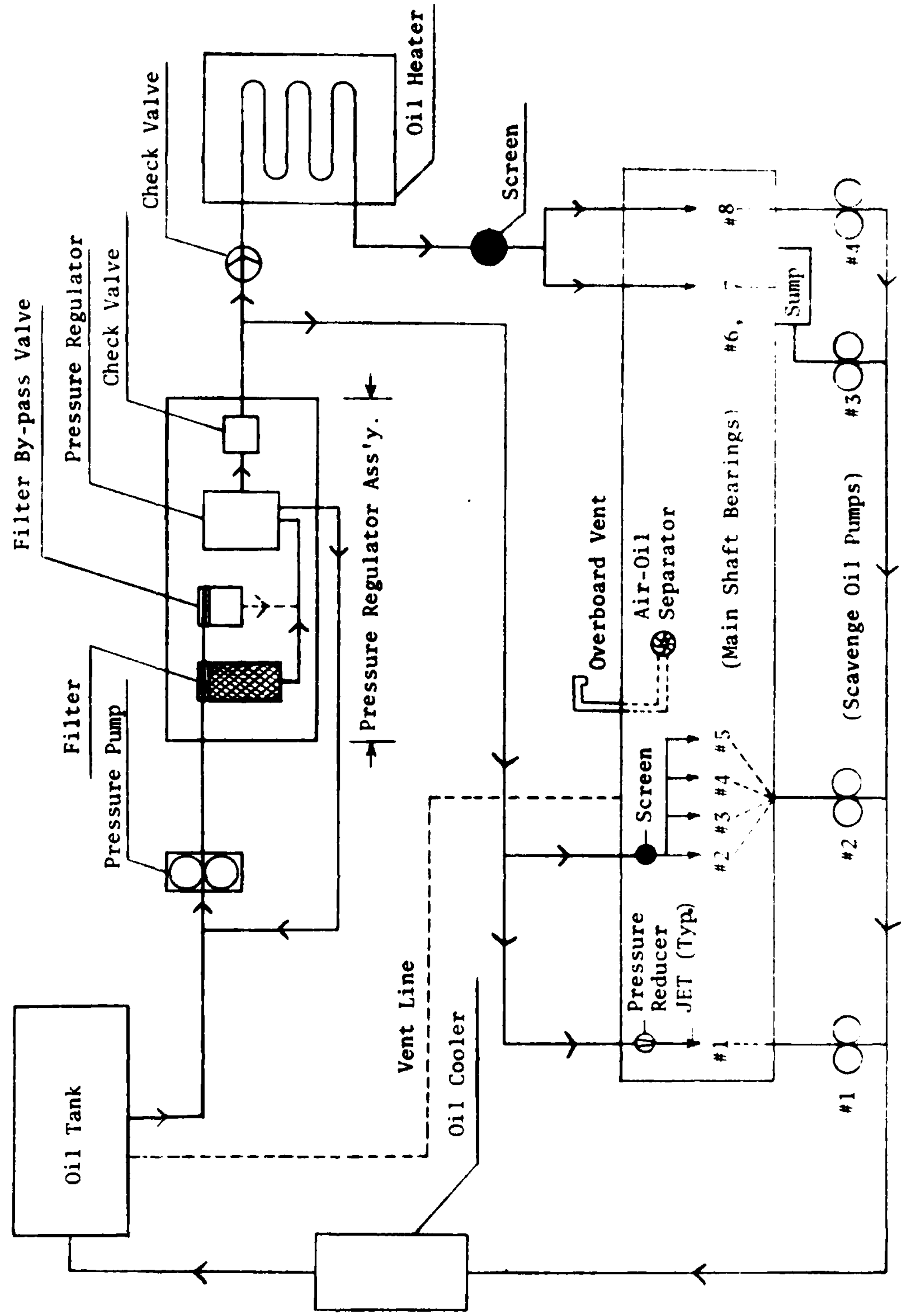


FIGURE 3: INITIAL TEST CYCLE

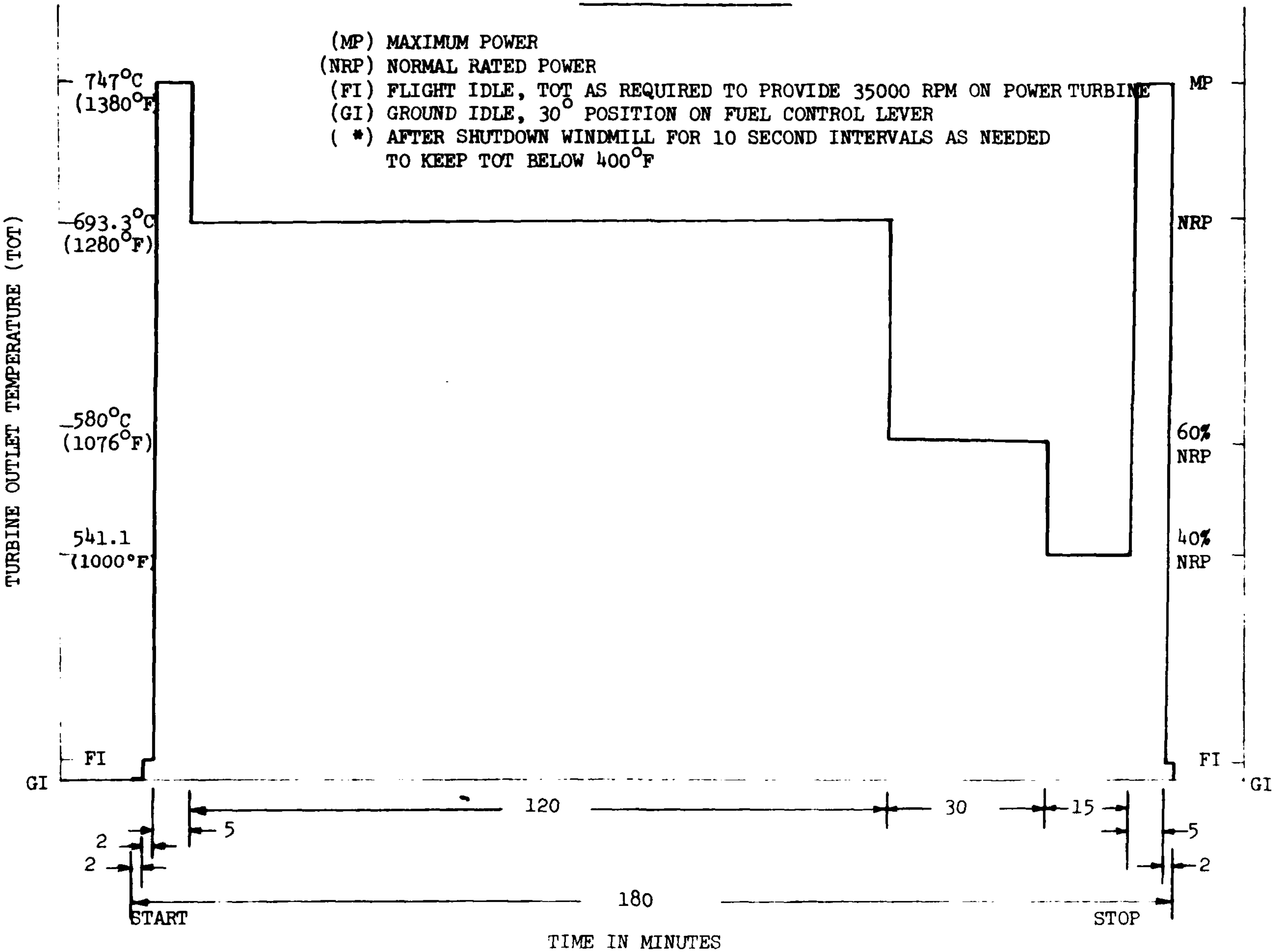


FIGURE 4: <u>TEMPERATURE OF BEARING NO. 7 VS TEMPERATURE OF OIL INTO THE HOT SECTION</u>

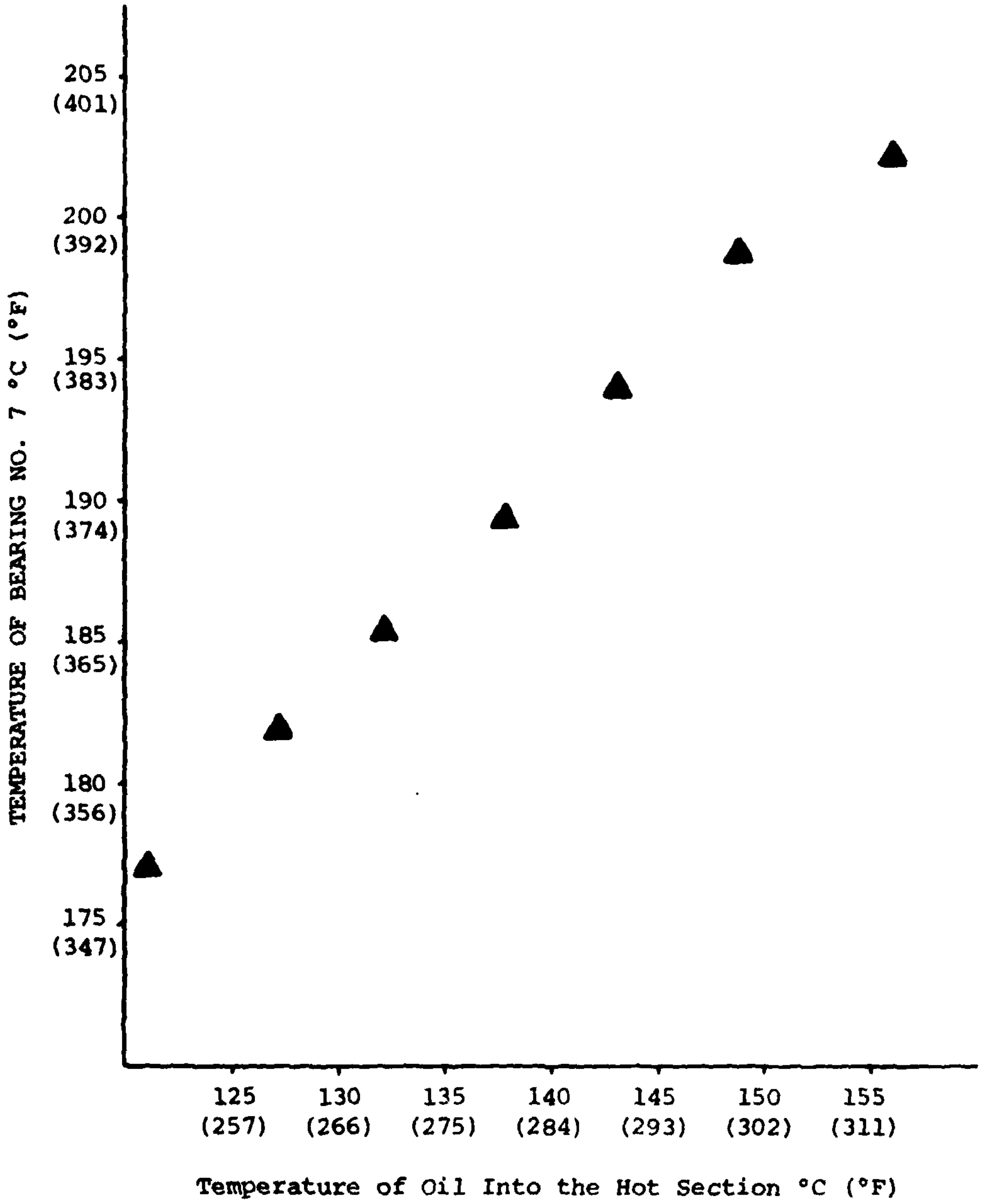


FIGURE 5: <u>TEMPERATURE OF BEARING NO. 8 VS TEMPERATURE OF OIL INTO THE HOT SECTION</u>

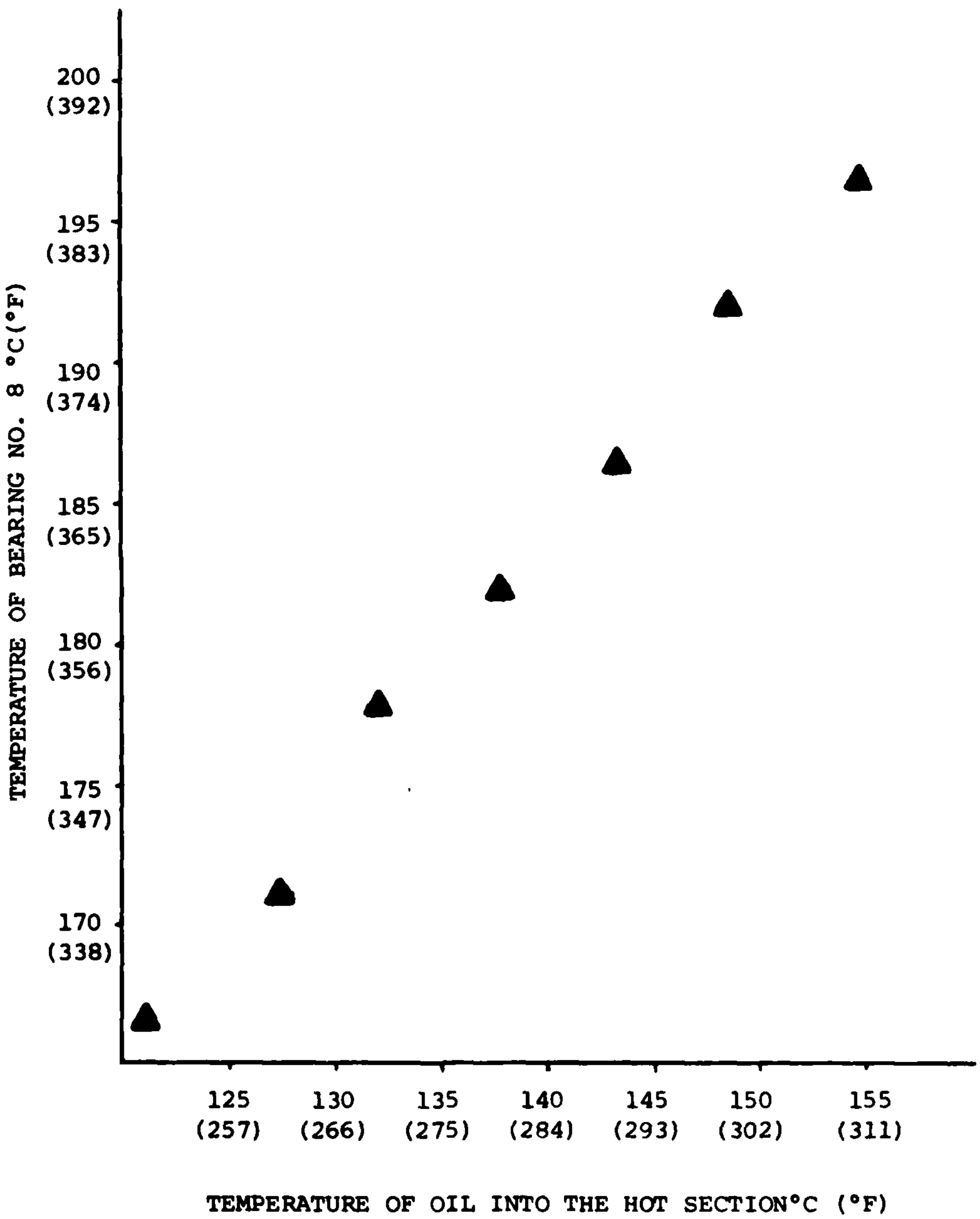


FIGURE 6: BEARING TEMPERATURE VS TURBINE OUTLET TEMPERATURE

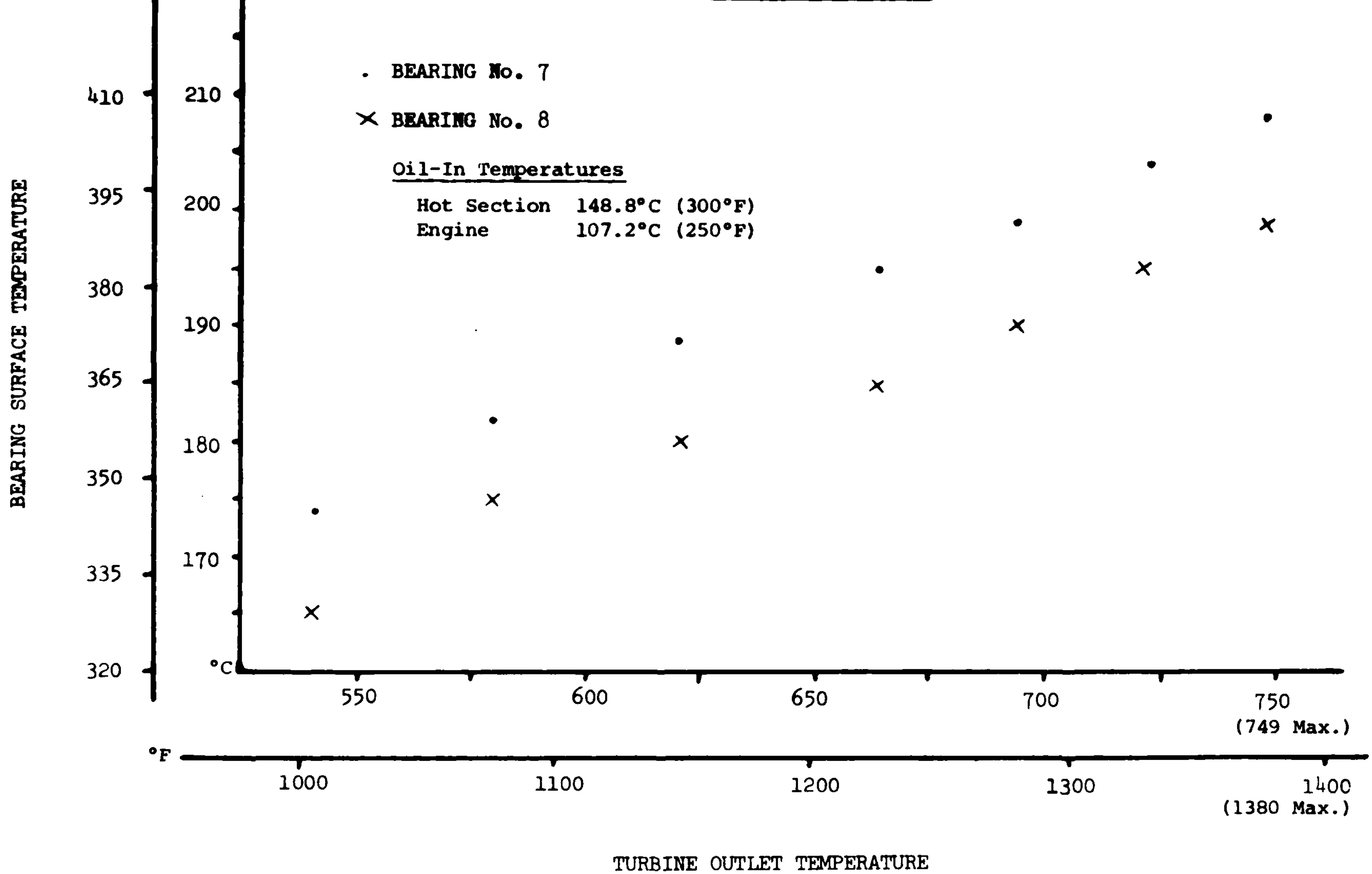


FIGURE 7: NO. 7 BEARING SOAKBACK TEMPERATURE PROFILE

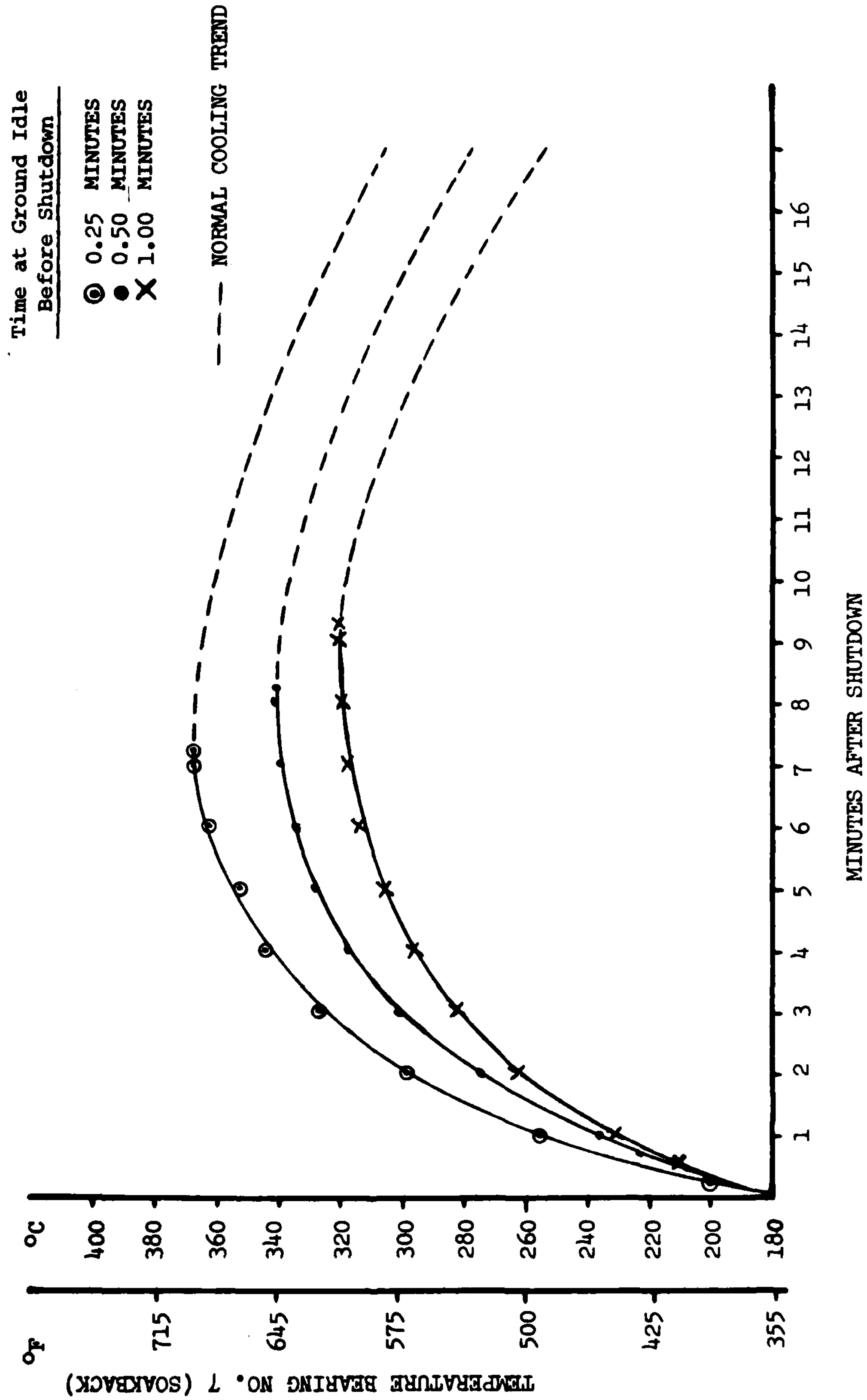


FIGURE 8: NO. 8 BEARING SOAKBACK TEMPERATURE PROFILE

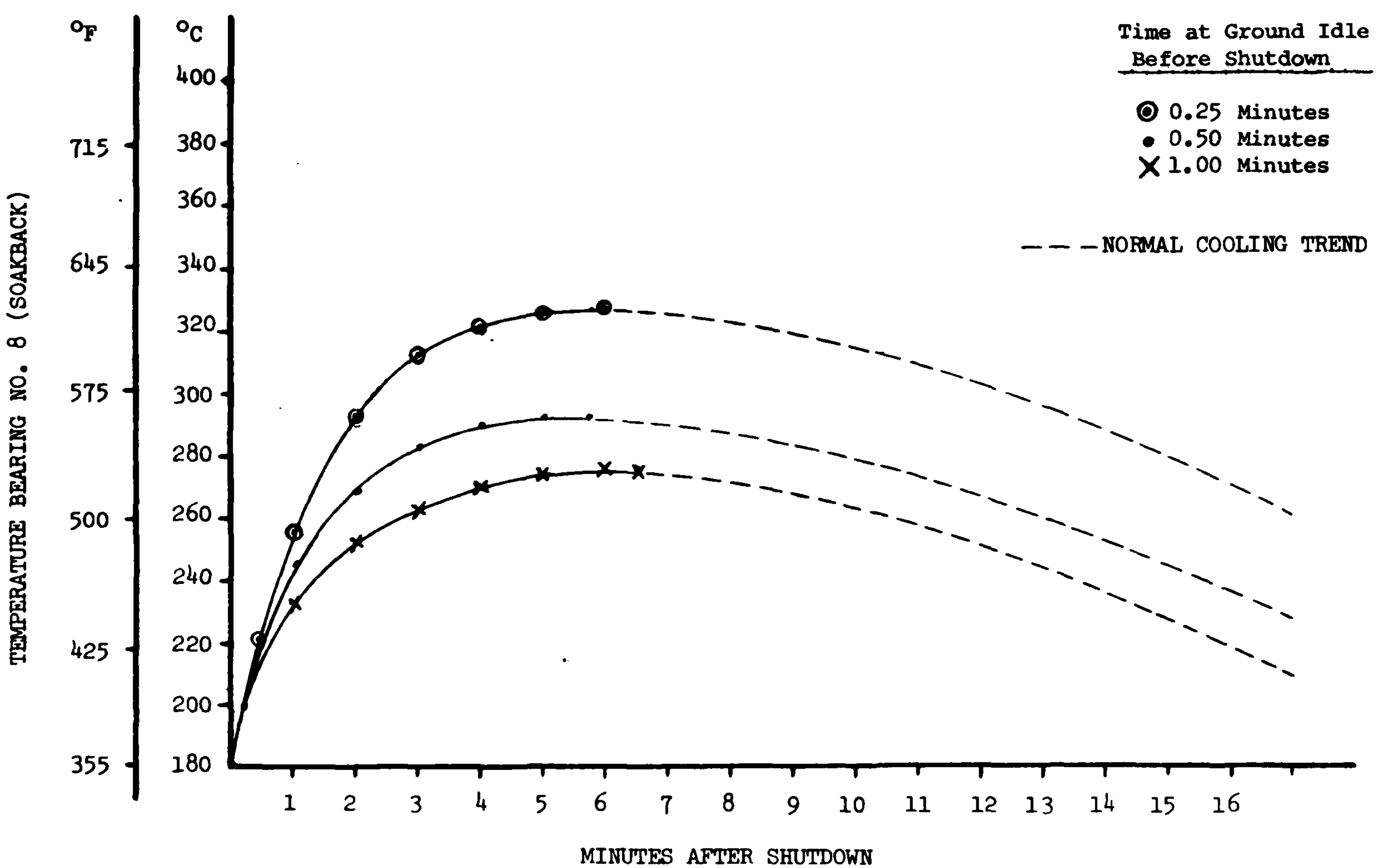


FIGURE 9: 1.5 HOUR TEST CYCLE

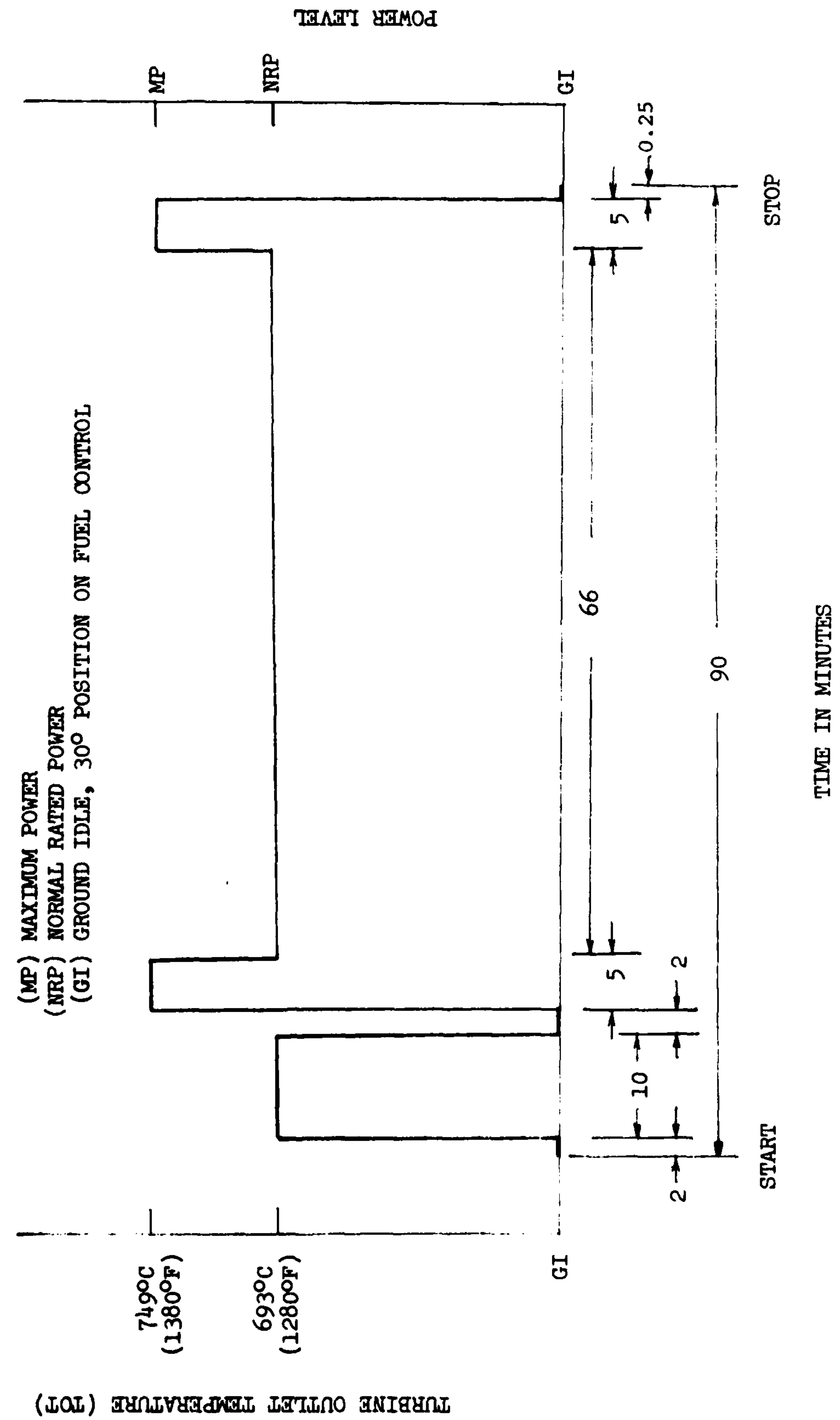


FIGURE 10: NUMBER 8 BEARING RETAINING PLATE STOCK T63-A-700

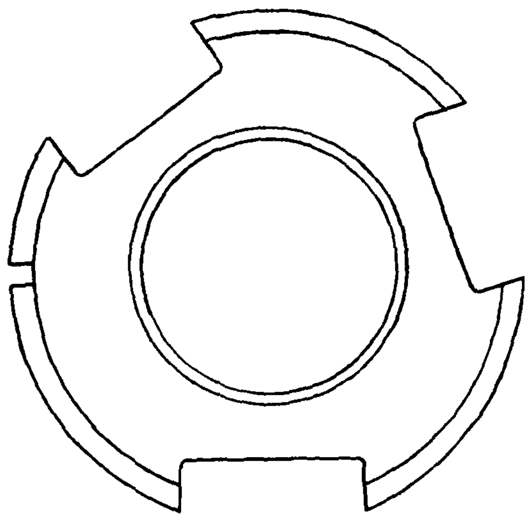
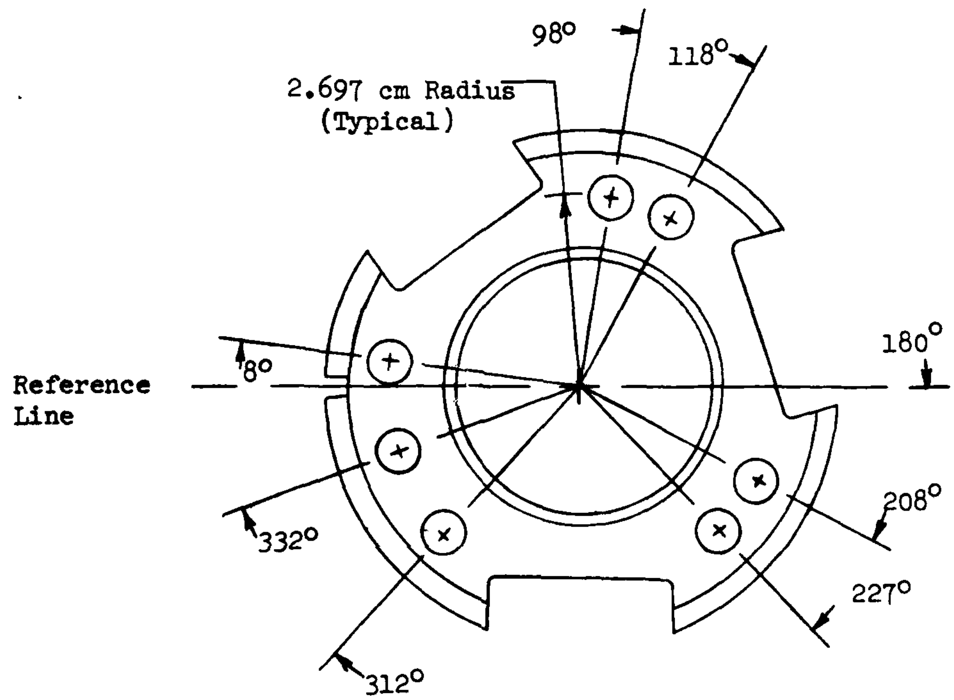


FIGURE 11: NUMBER 8 BEARING RETAINING PLATE

MODIFICATION 1



The plate was modified by drilling seven 0.635 cm (0.25 inch) diameter holes as indicated. Measurements are $\pm 2^{\circ}$ clockwise from the Reference Line.

FIGURE 12: 1.33 HOUR FINALIZED TEST CYCLE

(MP) MAXIMUM POWER
(NRP) NORMAL RATED POWER
(GI) GROUND IDLE, 30° POSITION ON FUEL CONTROL

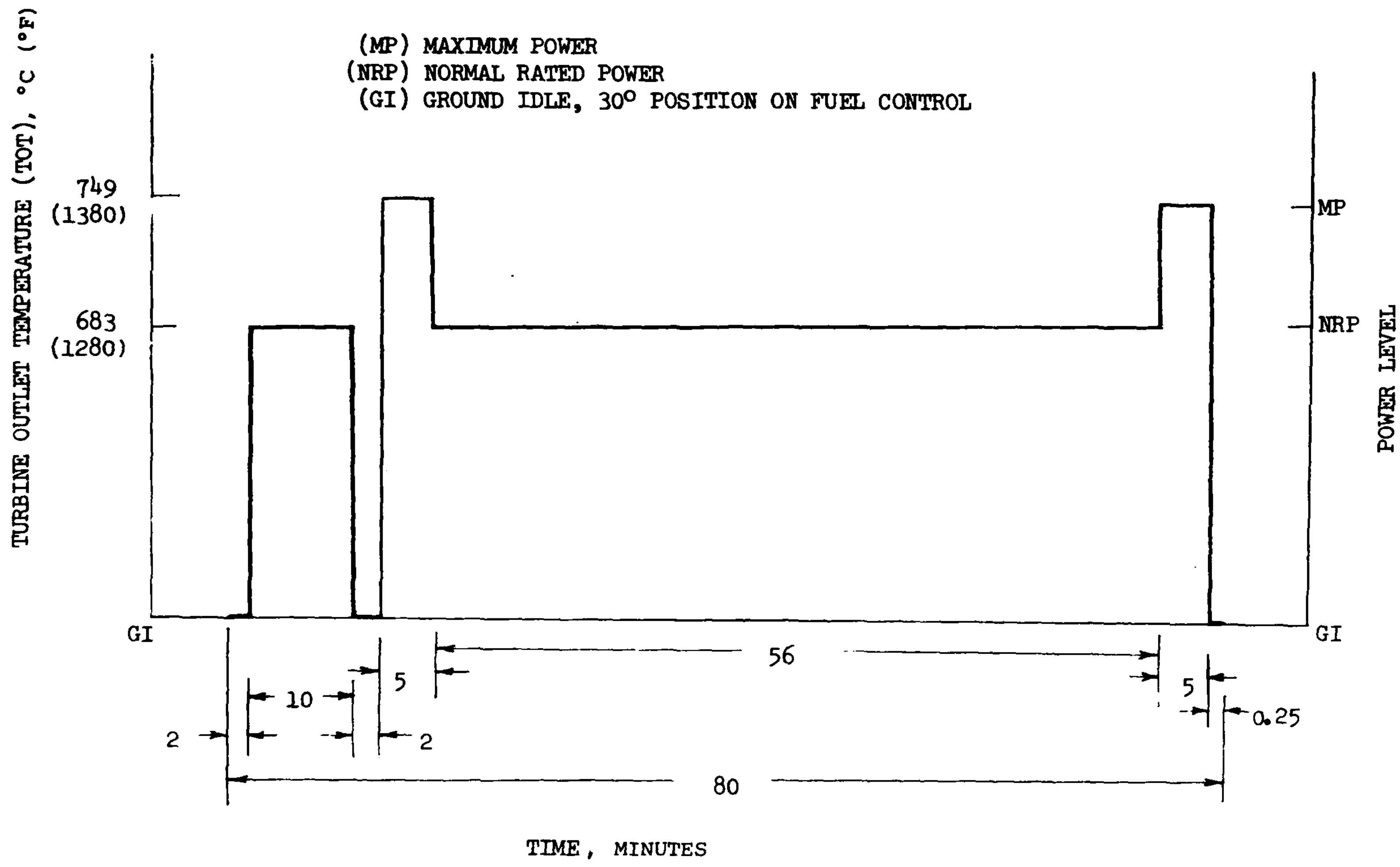
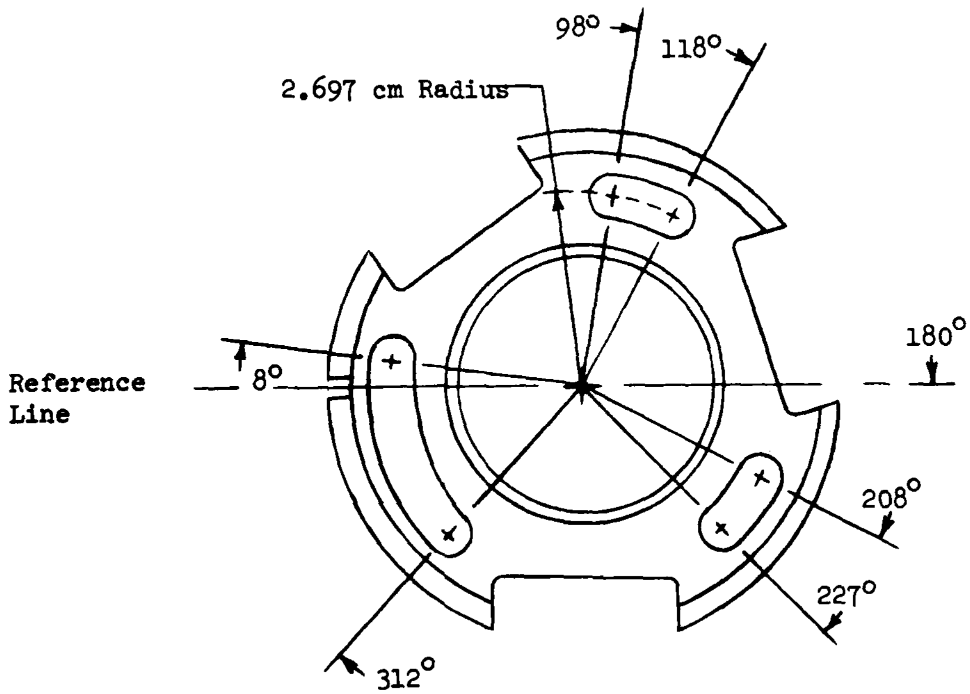


FIGURE 13: NUMBER 8 BEARING RETAINING PLATE

MODIFICATION 2



The plate was modified by machining three 0.635 cm (0.25 inch) minor diameter slots as indicated. Measurements are ± 2° clockwise from the Reference Line.

FIGURE 14; USED OIL ANALYSIS, PHASE III - FIRST TEST

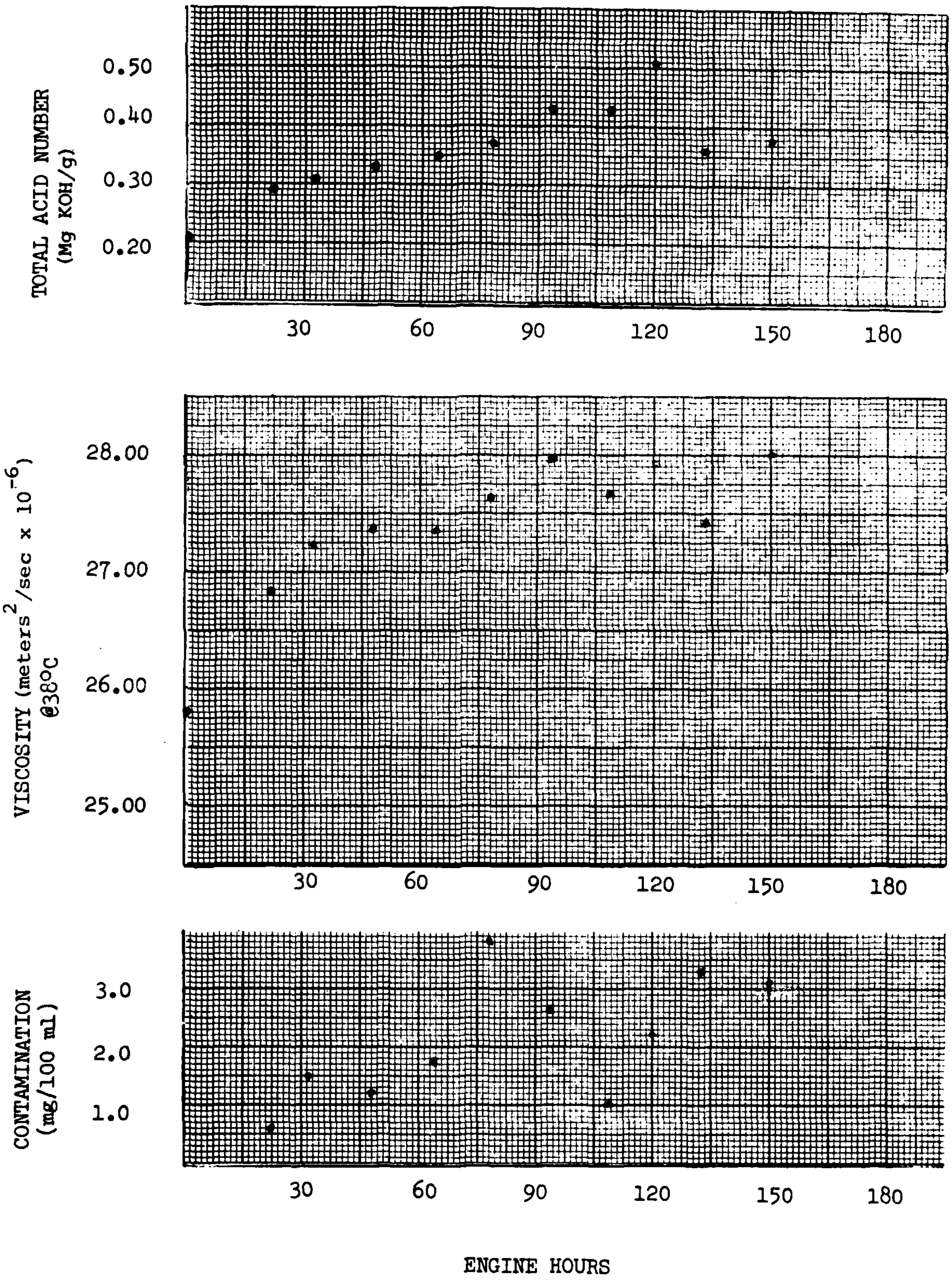


FIGURE 15: USED OIL ANALYSIS, PHASE III - SECOND TEST

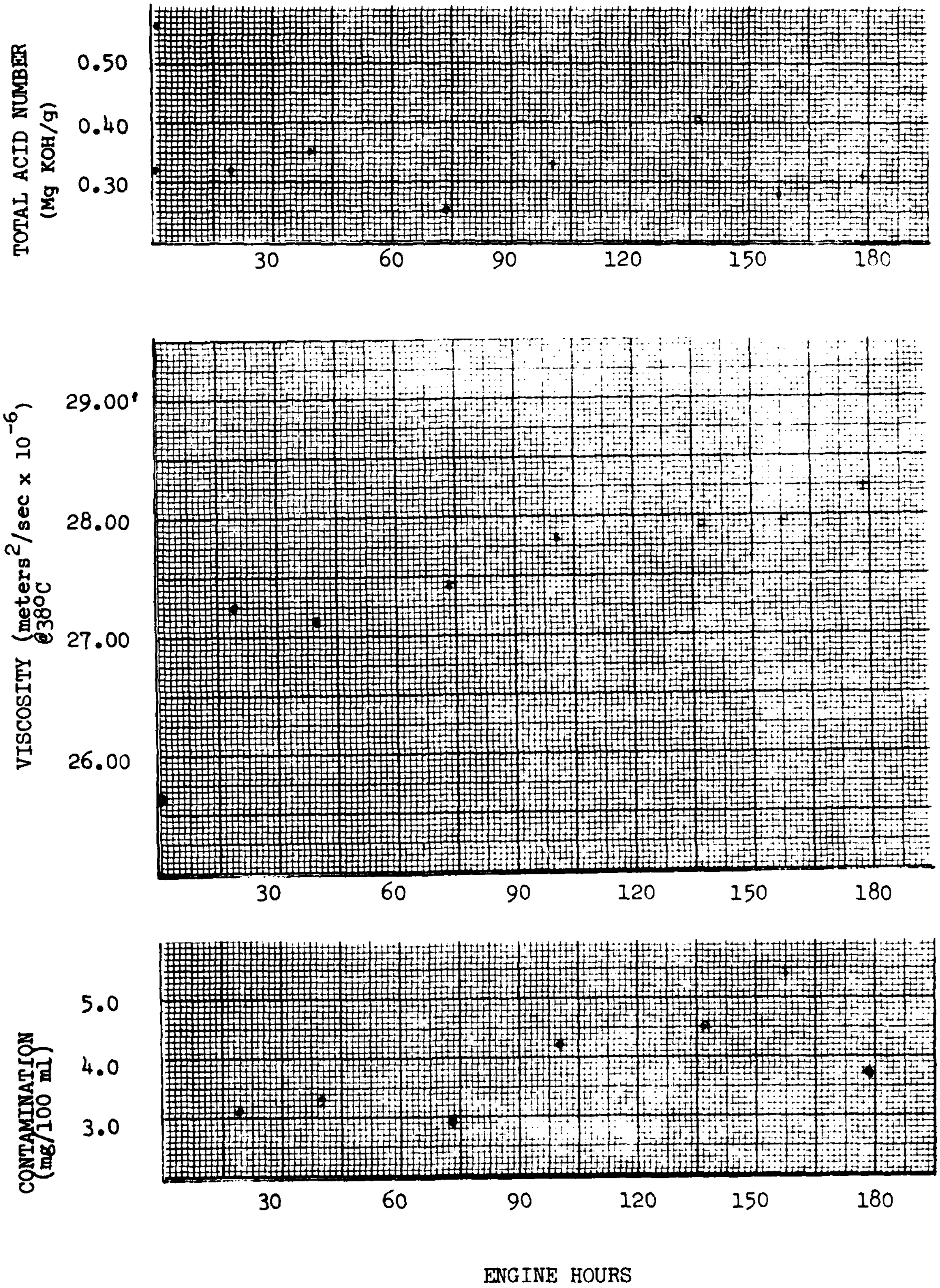


FIGURE 16: USED OIL ANALYSIS, PHASE III - THIRD TEST

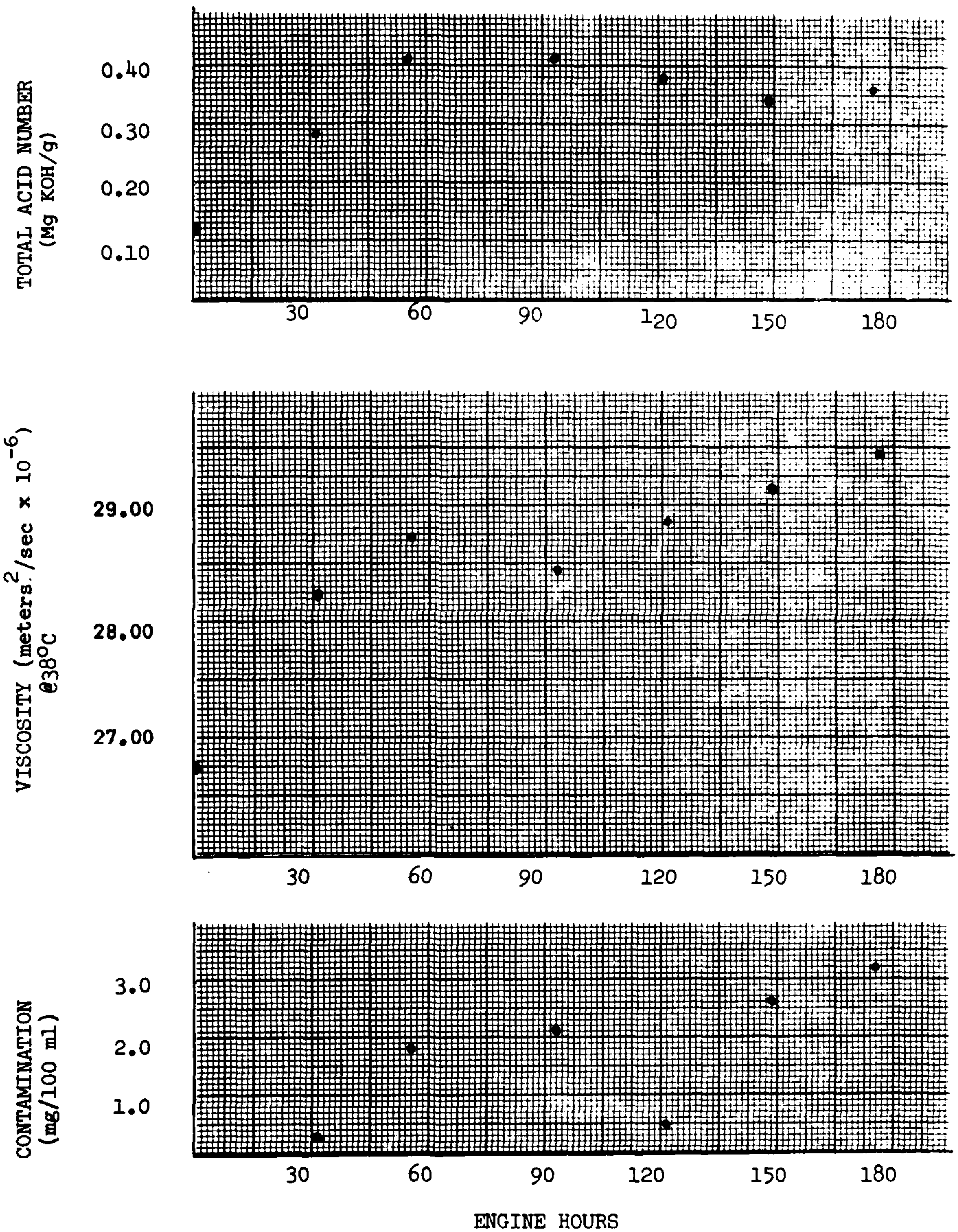


FIGURE 17: TYPICAL BEARING NO. 8 TEMPERATURE PROFILE DURING OPERATION AND SOAKBACK CYCLES

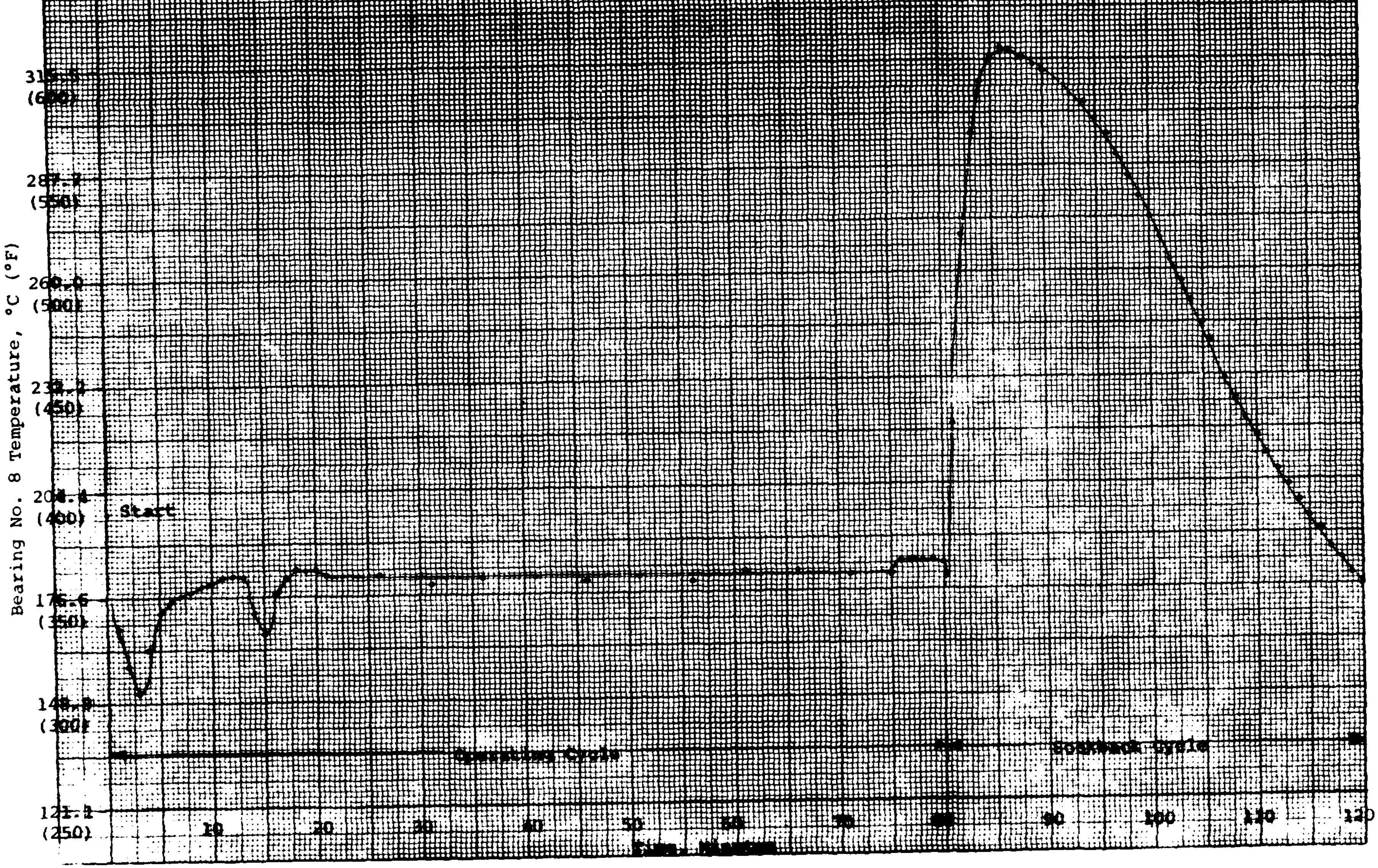


FIGURE 18: TYPICAL BEARING NO. 7 SOAKBACK TEMPERATURE CHARACTERISTIC FOR EACH OF PHASE III TESTS

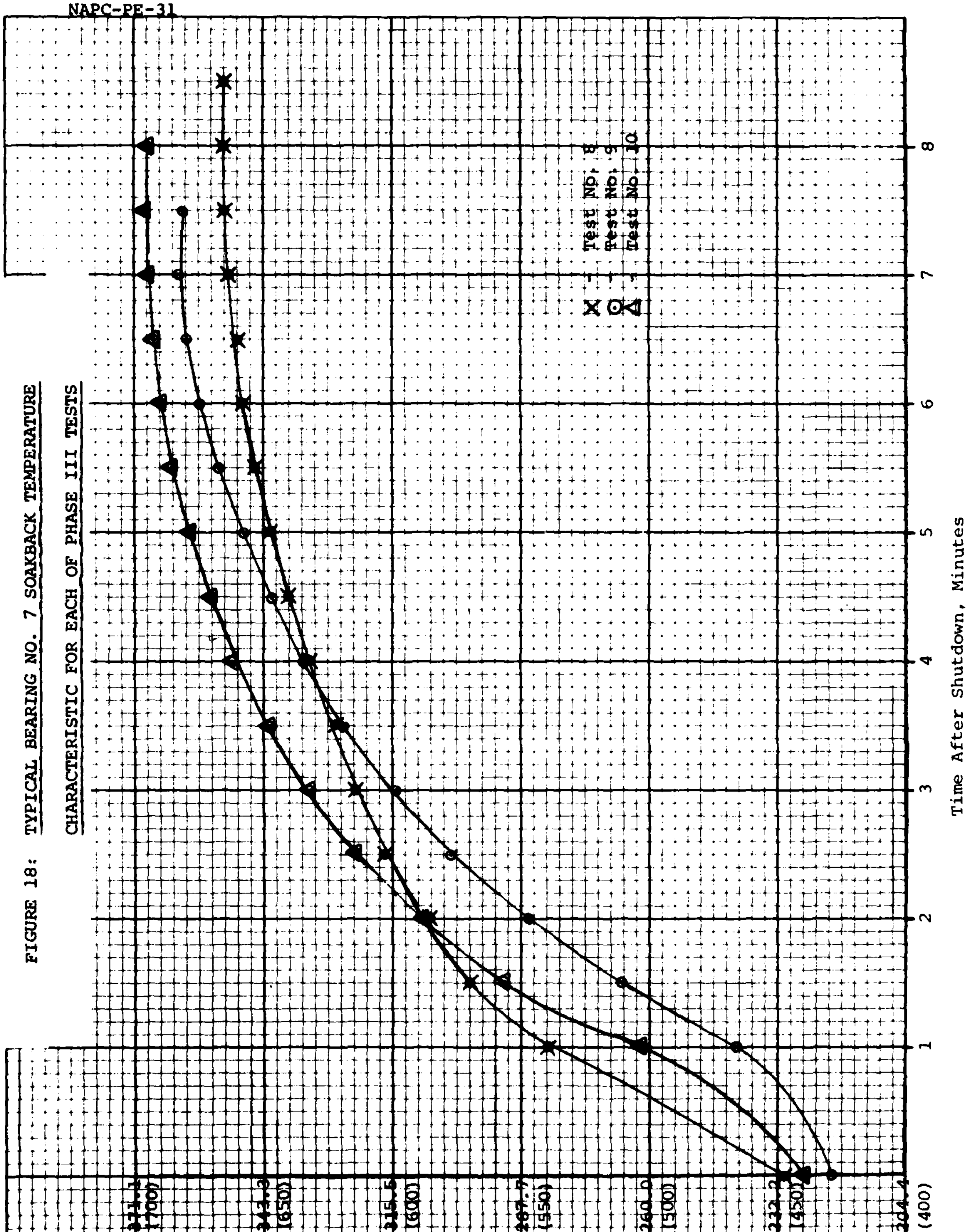
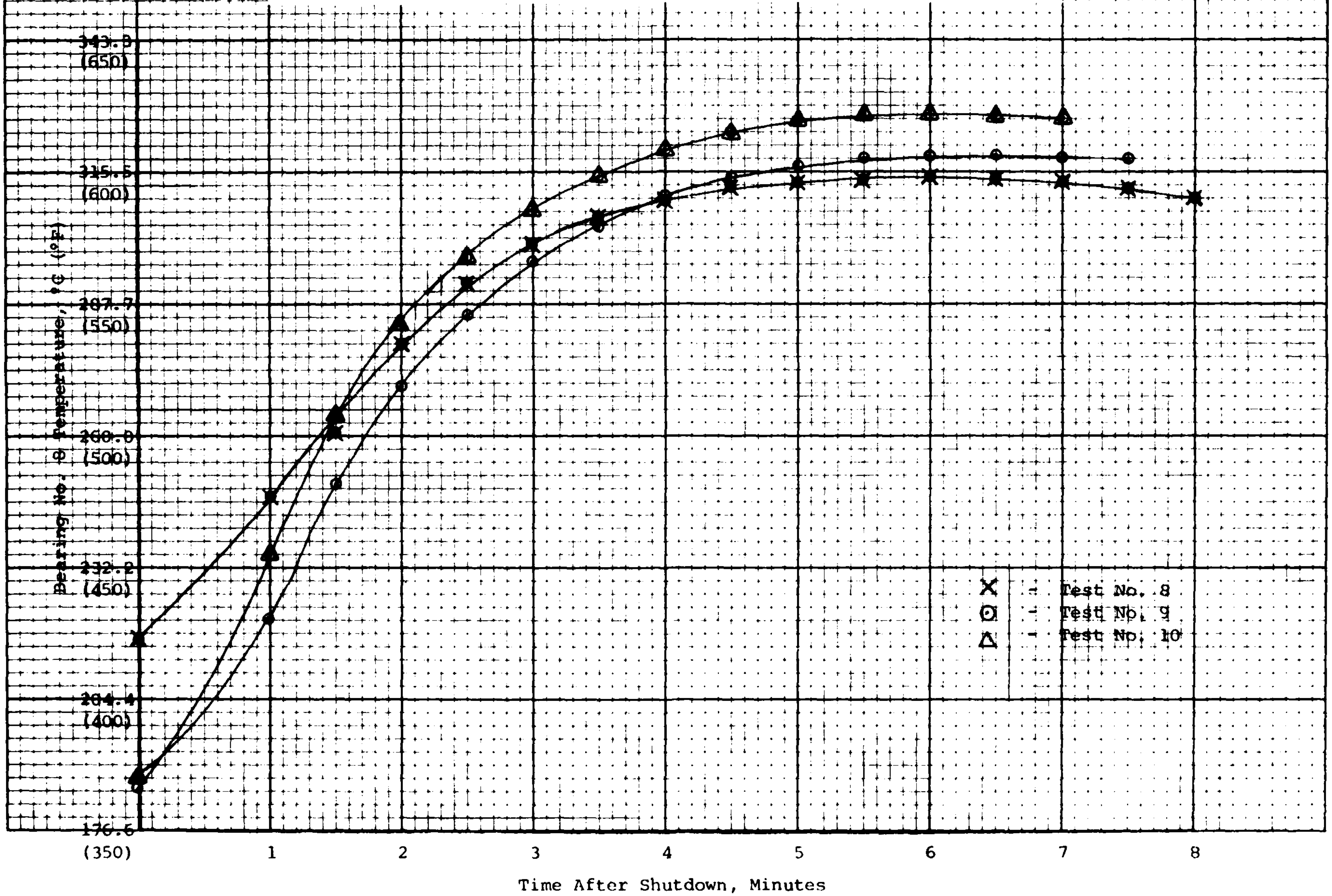


FIGURE 19: TYPICAL BEARING NO. 8 SOAKBACK TEMPERATURE CHARACTERISTIC FOR EACH OF PHASE III TESTS



REFERENCES

1. LETTER: Naval Air Propulsion Center, AEF2:FF:bc 10350 Ser F374 of 26 July 1971

2. LETTER: Naval Air Propulsion Center, AEF2:FF:vc 10350 Ser F420 of 8 November 1971

3. AUTHORIZATION: NAVAIR Work Unit Assignment NAPC-4R6 315 of July 1972

4. PROJECT: NAPC-4R6 315/10 of 20 September 1972

5. DRAWING: NAPC Drawing No. J-284, Engine Test Stand and Installation - Room D

6. DIRECTIVE: Test Directive for Full Scale Qualification Testing of Lubricating Oils under MIL Specification XAS-2354 of 6 August 1973

APPENDIX A

TEST DIRECTIVE

LUBRICANT QUALIFICATION TEST IN THE T63 ENGINE

Ref: (a) Specification: Experimental Development Specification XAS-2354A, Lubricating Oil Aircraft Turbine Engine, Synthetic Base, of 8 November 1974
(b) Specification: Military Specification MIL-L-23699B Amendment 2, Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, of 22 November 1971
(c) Depot Maintenance Work Requirement for Engine Assembly, Models T63-A-5A and T63-A-700. (USAAVSCOM DMWR-55-2840-231) U.S. Army Aviation Systems Command, St. Louis, MO

Encl: (1) Modifications of the Number 8 Bearing Compartment
(2) 1.33 Hour T63 Engine Test Cycle

1. Title: Full Scale Engine Test for Qualification of Lubricating Oils Under Military Specification MIL-L-23699B and XAS-2354A.

2. Personnel Assignments:

a. A. J. D'Orazio, Program Manager, PE72
b. P. A. Karpovich, Project Engineer, PE72
c. J. T. Shimski, Test Engineer, PE72

3. Purpose of Test: The purpose of this test is to evaluate the performance of the candidate lubricant in the T63 turboshaft engine. This test is the final step in the qualification of lubricating oils under Military Specification MIL-L-23699B and XAS-2354A.

4. Test Installation:

a. Engine - The T63 engine is to be located in the sea level test cell, Room "D", of the Accessory Test Area. It is to be installed in accordance with NAPC installation drawing number J-284 dated 27 February 1975 entitled "Installation, T63 Engine, Test RM "D"".

b. All test engines used in the Lubes Qualification Program will be overhauled prior to test use. Specifically, during overhaul, the oil wetted parts are to be cleaned to an "as new condition" to permit fair evaluation of the deposition characteristics of candidate lubricants by comparison to a common starting point.

c. The test engines will also have their number 8 bearing housings modified as shown in Enclosure (1). This modification consists of installing a bearing anti-rotation plate in the bearing housing area. To install this plate it is necessary to machine the bearing housing and replace the existing packing type seal with a crush type metallic "U" ring seal. Exact machining details for installation of the bearing retaining plate can be found in Chapter 6 of reference (c).

d. The engines used in the Lubricating Oil Qualification Test Program are equipped with three skin thermocouples in the turbine section. These thermocouples are inserted into the turbine rotor support housings. One in common number 6 and 7 bearing compartment of the power turbine support and the other two on the number 8 bearing housing in the gas turbine support (GTS). The first thermocouple in the GTS, gains access through a hollow support strut and is tack welded to the outer wall of the number 8 bearing compartment. This thermocouple is a skin type and is located in a static area of the gas path bordered by the stationary GTS and the rotating first stage gas turbine wheel. The second and third thermocouples are also skin type. They are tack welded to the outer wall of the number 6-7 and number 8 bearing housings and are entirely oil wetted. To gain entry, both the second and third thermocouples must penetrate a hot air cavity before entering the bearing compartments. The cavity is bridged using a stainless steel tube inserted via a hole drilled into the case. It is passed down a hollow support strut and through a hole drilled into the bearing compartment wall. The tube is then welded outside the case to a tube fitting on one end and silver soldered to the wall of the bearing compartment on the other. This method assures positive sealing.

5. <u>Instrumentation</u>:

a. The "D" Room test cell is equipped with a computerized data acquisition system which will be utilized during the test. The system will acquire data from all sources, i.e. thermocouples, pressure taps, flows, etc., and present the data in hard copy printouts at the end of each days operation. Also, the computer will perform diagnostic checks on selected parameters and present the data on a cathode-ray tube, CRT, in the control room immediately after acquisition. Any parameter out of specified limits is to produce an "out of limits" flag on the CRT display. Key parameters will be presented on gauges in the control room for the operators reference and for use as a back up to the data acquisition system. Should the system fail, the data will then be recorded by hand. The acquisition system program is to be such as to permit input of the missing data on cards after the malfunction has been corrected. Parameters to be recorded, their method of display, range and diagnostic limits are listed in the attached Table.

b. <u>Accuracy</u>: The test cell instrumentation is to be calibrated semi-annually so as to insure the reported data will have accuracy within the current limits specified for that equipment by the Measurement and Information Systems Department.

6. <u>Lubricating Oil System</u>:

a. The oil lines, oil tank and heat exchanger are to be cleaned prior to each test and inspected prior to installation by the test engineer. After installation of the oil lines, heat exchanger and the oil tank, apply insulation to the following: a) the oil tank; b) oil supply lines from the tank to the engine oil pump inlet and c) the engine high pressure oil lines between the oil pump outlet and the turbine section. Also at this time insulate the engine furnished scavenge sump tank beneath the common number 6 and 7 bearing compartment on the Power Turbine Support.

b. Oil Preheat Tank: Engine oil which enters the rear bearing areas (bearings No. 6, 7 and 8) of the turbine section of the engine is to be heated to 149°C ±2°C (300°F ±5°F) for qualification testing by means of a coil immersed in a heating transfer media.

7. Operating Limits (Static Sea Level):

a. T_5, Maximum, Start 927°C (1700°F)

b. Oil-in Temperature Turbine Section Maximum, 151°C (305°F) Compressor and Gearbox Section, Maximum 127°C (260°F)

c. Power Turbine Speed (Nf), Maximum 37,800 RPM

d. T_5, Maximum, Normal Rated Power 693°C (1280°F)

e. T_5, Maximum, Maximum Power, 30 Minute Maximum 749°C (1380°F)

f. Oil Pressure, Minimum, Ground Idle 3.45×10^5 Pag (50 psig)
Oil Pressure, Maximum, MIL + NR 8.96×10^5 Pag (130 psig)

g. Vibration-Compressor, Vertical, Transient, Maximum, 5.08×10^2 m/sec (2.0 in/sec) - Compressor, Vertical, Steady State, Maximum 3.81×10^2 m/sec (1.5 in/sec)

h. Torque, Power Take-Off, Maximum Steady State 4.0×10^2 N-m (3516 in-lb)
Torque, Power Take-Off, Steady State 3.4×10^2 N-m (2988 in-lb)

8. Pre-Test Engine Test:

a. Fill the oil lubricating system with six quarts of the candidate oil and run at ground idle for a minimum of five minutes with the oil-in temperature (both sections) stabilized at 121°C (250°F). Shutdown and check for oil leaks. Repair leaks, if any, and repeat this run until the system is "tight".

b. The engine performance check run is then made at the following power settings with oil-in at 121°C (250°F): Ground Idle (GI) Flight Idle (FI), 40% Normal Rated Power (NRP), 60% NRP, 75% NRP, 90% NRP, 100% NRP and Maximum Power (MP). Each power setting is held for 5 minutes. Data is recorded when all parameters have stabilized. Engine performance is to be within ten percent of specified power limits at the proper turbine exhaust gas temperature conditions.

c. Proceed with the oil consumption test as per paragraph 9.

9. Oil Consumption Test:

a. Run a two hour consumption cycle with the oil temperature to both sections controlled at 121°C (250°F). The cycle consists of ten minutes at GI, one hundred minutes at NRP followed by ten minutes at GI. After the run is completed allow the engine to cool to room temperature and top-off the tank to the "full" mark. Determine the oil consumption from the amount added. Oil consumption is not to exceed 189 cm^3 per hour.

b. Drain oil from the tank, sump, lines and cooler and replace with new oil.

10. <u>175-Hour Endurance Cycle</u>: (See Enclosure 2)

a. Run 131 cycles of 1.33 hours each as described below:

Condition	NPT, RPM	Time, Min.	Shaft Horsepower, Watts (hp)	TOT, °C (°F)
Start	-	-	-	927 (1700)
Ground Idle	-	2	2.6×10^4 (35) max.	454 (850)
Normal Rated Power	35,000	10	2.0×10^5 - (270)	693 (1280)
Ground Idle	-	2	2.6×10^4 (35) max.	454 (850)
Max. Power	35,000	5	2.4×10^5 (315)	749 (1380)
Normal Rated Power	35,000	56	2.0×10^5 - (270)	693 (1280)
Max. Power	35,000	5	2.4×10^5 (315)	749 (1380)
Ground Idle	-	0.25	2.6×10^4 (35) max.	454 (850)
Stop	-	-	-	-

Run TOT necessary to obtain SHP (If TOT necessary is above maximum allowable run at maximum allowable TOT for condition).

Total Time (1-cycle) 80 minutes = 1.33 hours

b. Repeat cycle after a 40 minute shutdown period.

c. Controlled temperature of engine oil-in to turbine sections (No. 6, 7 and 8 areas) shall be 149°C (300°F) all other oil held at 121°C (250°F).

d. Oil samples, as described in paragraphs 11b and 11c are to be taken immediately following engine shutdown. Oil is added before starting each day and the amount recorded in cubic centimeters on the oil log sheet supplied to the test cell by the test engineer.

e. Record engine data, per cycle, in accordance with the following schedule. After starting and when in the First Normal Rated Power (NRP) plateau, record data at five and at eight minutes after stabilizing at the power setting. The third data point of the cycle is acquired at the Ground Idle power setting following the ten minute NRP plateau. The reading is taken one minute after the setting has stabilized. When operating at maximum power at two points in the cycle, data is acquired two minutes after the power setting has stabilized. During the second NRP plateau the data is recorded at fifteen minute intervals starting from when the power setting has stabilized. Data is also recorded after shutdown, however, only from the three thermocouples in the turbine section. This data is to be acquired at fifteen second intervals beginning forty-five seconds after the engine is shutdown and continuing until all three measured temperatures have reached maximum values.

11. Oil Sampling:

a. The oil sampling procedure is as follows: Immediately after engine shutdown (using asbestos gloves, if necessary) hold a clean sample bottle under the sampling value of the tank, open the valve and fill the bottle. Then take a clean bottle and draw another oil sample from the tank. Finally, pour the initial sample back into the tank.

b. Draw a 50 cm^3 oil sample for lubricant physical/chemical analysis every 20 cycles of operation.

c. Draw a 25 cm^3 sample for spectrometric analysis every 8 cycles of operation.

d. Identify the oil samples with test number, oil time, oil code number engine serial number, and date drawn.

e. Record the sample size and oil time in the supplied oil log and also on the cycle data sheet.

12. Post Test Procedure: After completion of the 175-hour endurance test:

a. Drain the lubricating oil system as thoroughly as possible into a clean two gallon can. A clean can is a new can which has been rinsed with alcohol and then blown dry with compressed air. Identify the contents as per paragraph 11d. The drained oil is to be retained for possible future analysis.

b. Remove the engine from the test cell and deliver it to the engine preparation shop.

c. Disassemble the engine and layout in the "dirty" condition for inspection.

MS REQUIREMENTS FOR T63 FULL SCALE ENGINE OIL TEST

	I.D. TAG	RANGE	CRT	DATA ACQUISITION	CONTROL ROOM	LIMIT
PRESSURES (PSIG)						
Engine Oil In	POPI	-15 to 30	*	*	*	
Engine Oil Main Filter In	POMF	0 - 250	*	*	*	200 MAX
Engine Oil Controlled Supply	POLS	0 - 160	*	*	*	50 MIN
Engine Oil Screen In	POSI	0 - 160	*	*	*	50 MIN
Engine Oil Screen Out	POSO	0 - 160	*	*	*	50 MIN
Differential Pressure Filter	PDMF	0 - 100	*	*	*	75 MAX
Differential Pressure Screen	PDOS	0 - 25	*	*	*	10 MAX
Fuel Into Pump	PFPI	0 - 60	*	*	*	5 MIN
Air Final Stage Compressor	PACF	0 - 200			*	
		in.- Hg A		*		
Water in Waterbrake	PWBI	0 - 100		*	*	40 MIN
Accessory Gearbox	PAGB	0 - 30	*	*	*	20 H_2O
		in. H_2OG				
Engine Oil Scavenge	POSC	0 - 60	*	*	*	40 MAX
Compressor Inlet, Static	PSCI	in. HgA		*	*	
		24 - 30 (35)				
Exhaust Gas Static	PSEG	in. HgA		*	*	
		24 - 30 (35)				
Compressor Inlet Total	PTCI	in. HgA		*	*	
		24 - 35				
TEMPERATURES (DEG. F)						
Engine Oil Tank	TOTK	0 - 400	*	*	*	315 MAX
Engine Oil - In Heat Exchanger	TOHE	0 - 400	*	*		
Engine Oil - In Pump	TOPI	0 - 400	*	*	*	260° MAX
Engine Oil Sump	TOSP	0 - 600	*	*	*	425° MAX
Engine Oil Main Scavenge	TOSC	0 - 600	*	*	*	
Engine Oil in Hot Section	TOHS	0 - 400	*	*	*	330° MAX
Water in W/B	TWBI	0 - 200		*	*	
Water Out W/B	TWBO	0 - 200	*	*	*	180° MAX
Air Above The Engine	TAAM-1	0 - 150			*	
Air Engine Front Floor	TAAM-2	0 - 150			*	

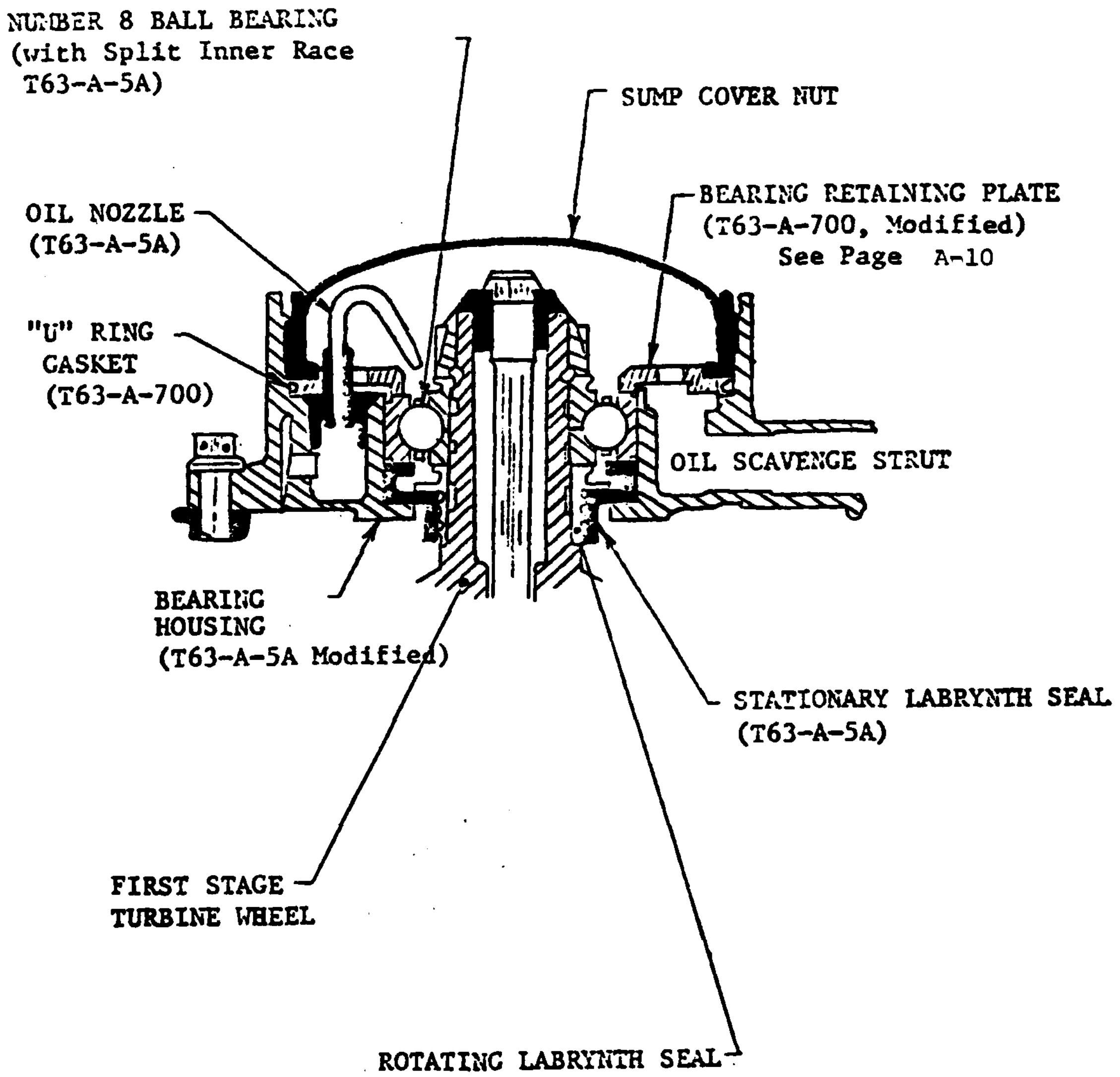
	I.D. TAG	RANGE	CRT	DATA ACQUISITION	CONTROL ROOM	LIMIT
Air Cell Sprinklers	TAAM-3	0 - 150			*	
Air Room Inlet Duct	TAAM-4	0 - 150			*	
Gas Producer Turbine Outlet Temp.	TOT	0 - 1800	*	*	*	1385 MAX
Air Bellmouth	TABM	0 - 150	*	*	*	
Port EGT	TGPE	0 - 1800		*		
Starboard EGT	TGSE	0 - 1800		*	*	
Metal Surface 1	TMSI	0 - 1000		*	*	900 MAX
Bearing #7	TBR7	0 - 1000	*	*	*	500 MAX
Bearing #8	TBR8	0 - 1000	*	*	*	500 MAX
Bearing Front Waterbrake	TBFB	0 - 250	*	*	*	150 MAX
Bearing Rear Waterbrake	TBRB	0 - 250	*	*	*	200 MAX
Fuel Inlet Temp	TFEI	0 - 100	*	*	*	
FLOW						
Fuel lb/hr	WF	40 - 400	*	*	*	
SPEED						
Gas Producer Turbine RPM	NGT	0 - 55K	*	*	*	53165 MAX
Power Turbine RPM	NPT	0 - 45K	*	*	*	37800 MAX
VIBRATIONS in/sec						
Compressor, Vertical	VCEV	0 - 10			*	1.5
Waterbrake, Vertical	VWBV	0 - 10			*	1.5
Waterbrake, Horizontal	VWBH	0 - 10			*	1.5
Turbine, Vertical	VTEV	0 - 10			*	1.5
Accessory Gearbox, Vertical	VGBV	0 - 10			*	1.5
OTHER						
PLA, Gas Turbine (DEG)	PLGT				*	
PLA, Power Turbine (DEG)	PLPT				*	
Torque, Waterbrake (in-lb)	TQWB	0 - 4000	*	*	*	3500
PARAMETER						
Warning Lights						
1. Chip Indicator (2)					*	
2. Low Oil Level					*	

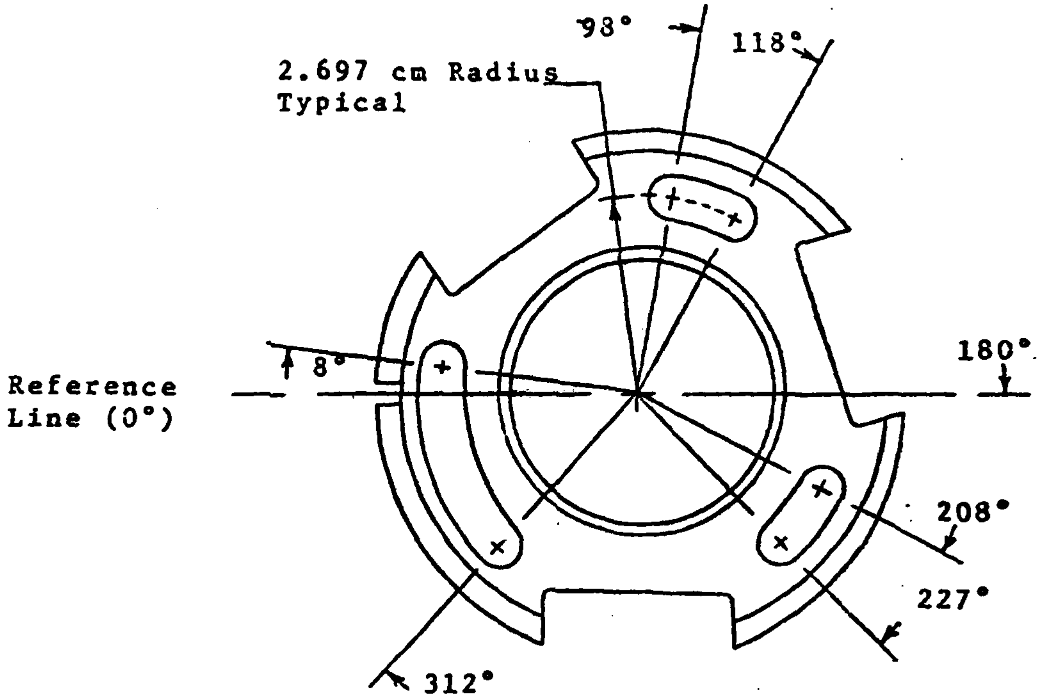
	I.D. TAG	RANGE	CRT	DATA ACQUISITION	CONTROL ROOM	LIMIT
INDICATING (RUNNING) LIGHTS						
1. Power to Fuel Pump					*	
2. Starter Switch					*	
3. Fuel Solenoid Switch					*	

NOTES:

1. Install overspeed protection in case of sudden loss of load.
2. Install electrical system for automatic temperature control of engine oil-in.
3. Install automatic temperature control to maintain temperature of oil to bearings in hot section (Bearing Nos. 6, 7 and 8) at 149°C (300°F).

MODIFICATIONS TO THE NUMBER 8 BEARING COMPARTMENT

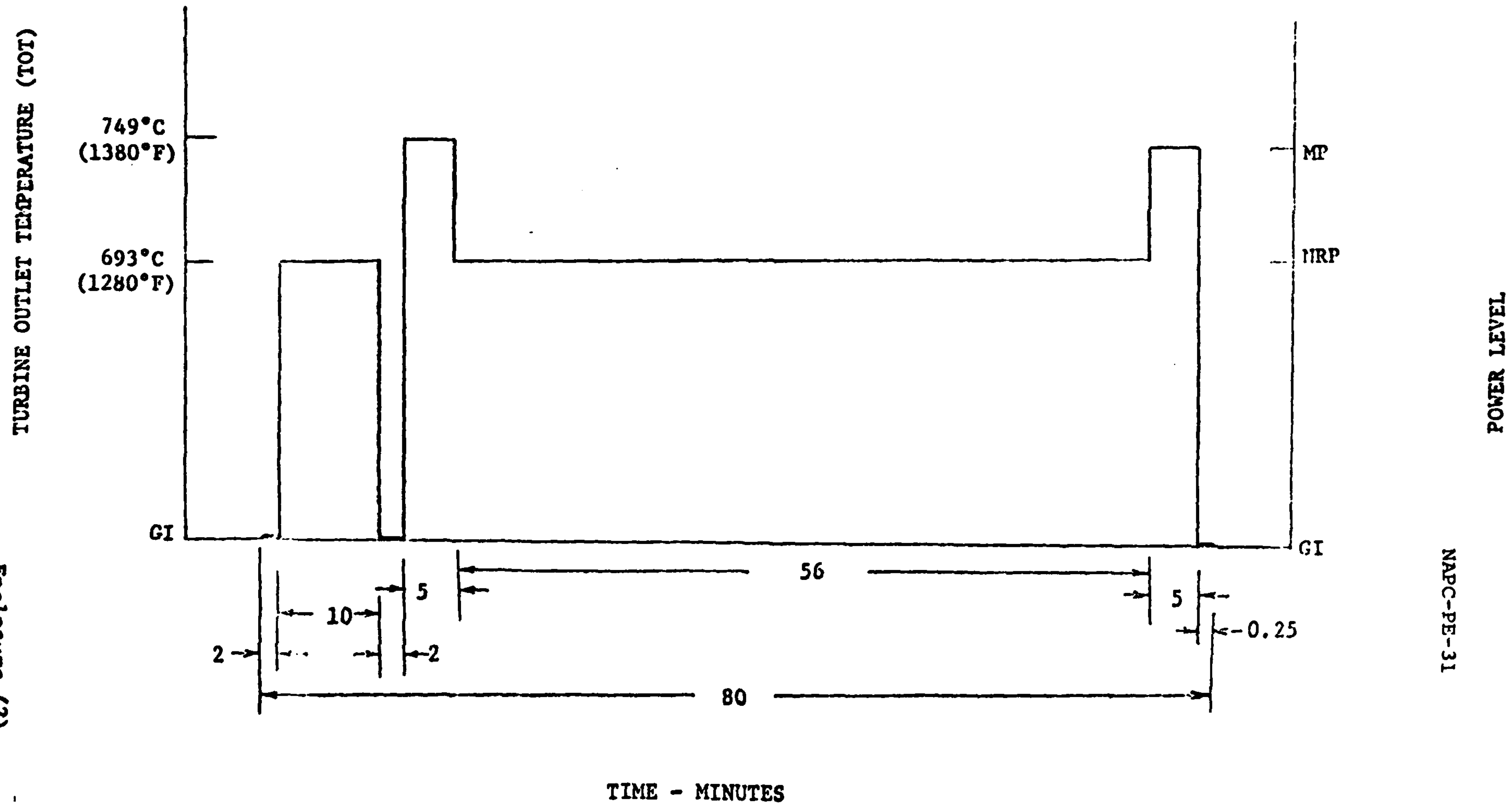




The plate is modified by machining three 0.635 cm (0.25 inch) minor diameter slots as indicated. Measurements are ±2° clockwise from the Reference Line.

1.33 HOUR TEST CYCLE

(MP) MAXIMUM POWER
(NRP) NORMAL RATED, POWER
(GI) GROUND IDLE, 30° POSITION ON FUEL CONTROL



APPENDIX B

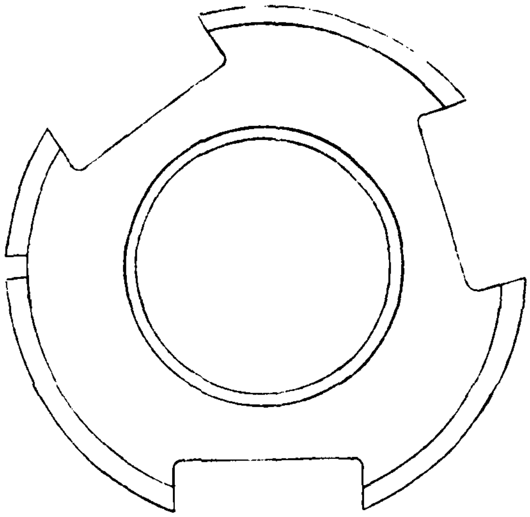
MODIFICATION TO THE NUMBER 8 BEARING COMPARTMENT

(BEARING RETENTION PLATE)

Rotation of the No. 8 bearing outer race in its housing had occurred during initial testing. This rotation was common in the T63-A-5A model and a "fix" for the problem was incorporated in the T63-A-700 "Blue Ribbon" Model. The modification consisted of machining off a portion of the bearing housing, which held the No. 8 retaining ring in the A-5A model, and replacing it with a stainless steel bearing retaining plate (Enclosure (1)). Since the retaining plate is held in place by the No. 8 compartment sump cover nut it was also necessary to modify the sealing method for the nut to that used in the A-700 model. Illustrations of the two standard model configurations of T63 No. 8 bearing compartments are shown in Enclosures 2 and 3.

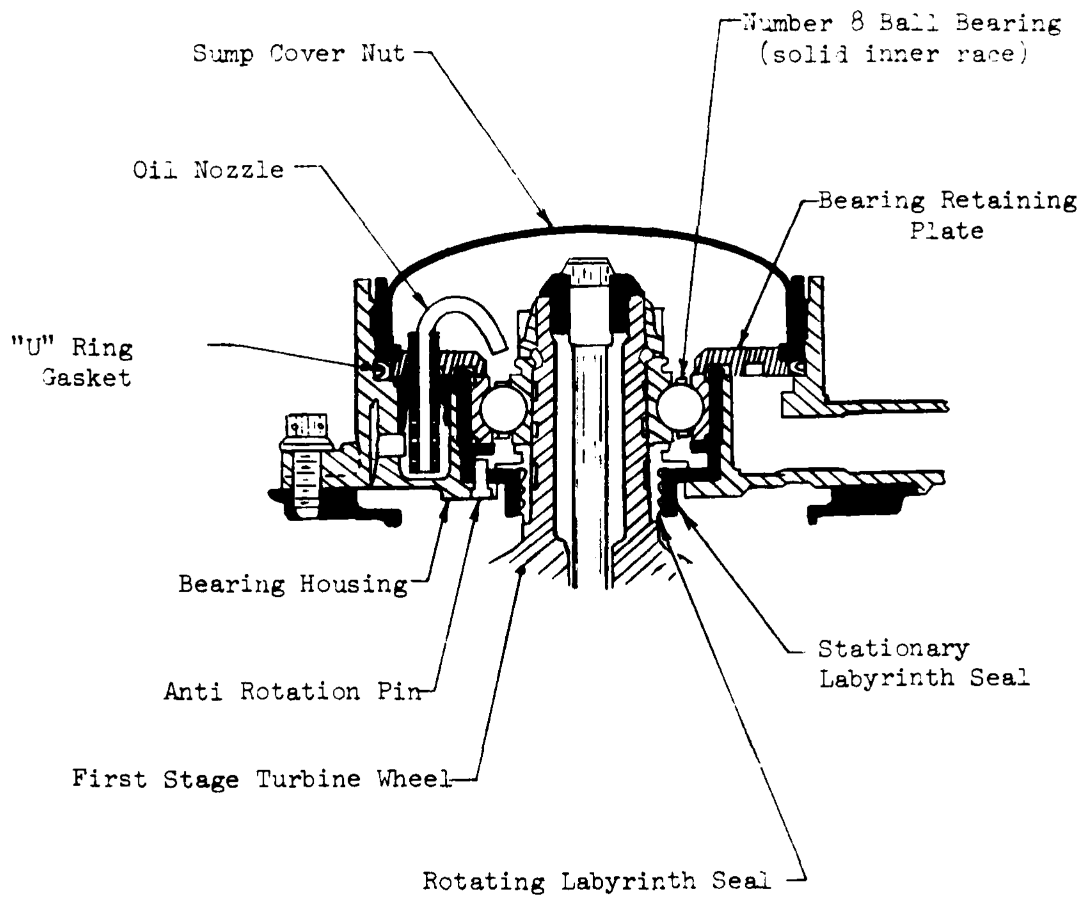
NUMBER 8 BEARING RETAINING PLATE

STOCK T63-A-700



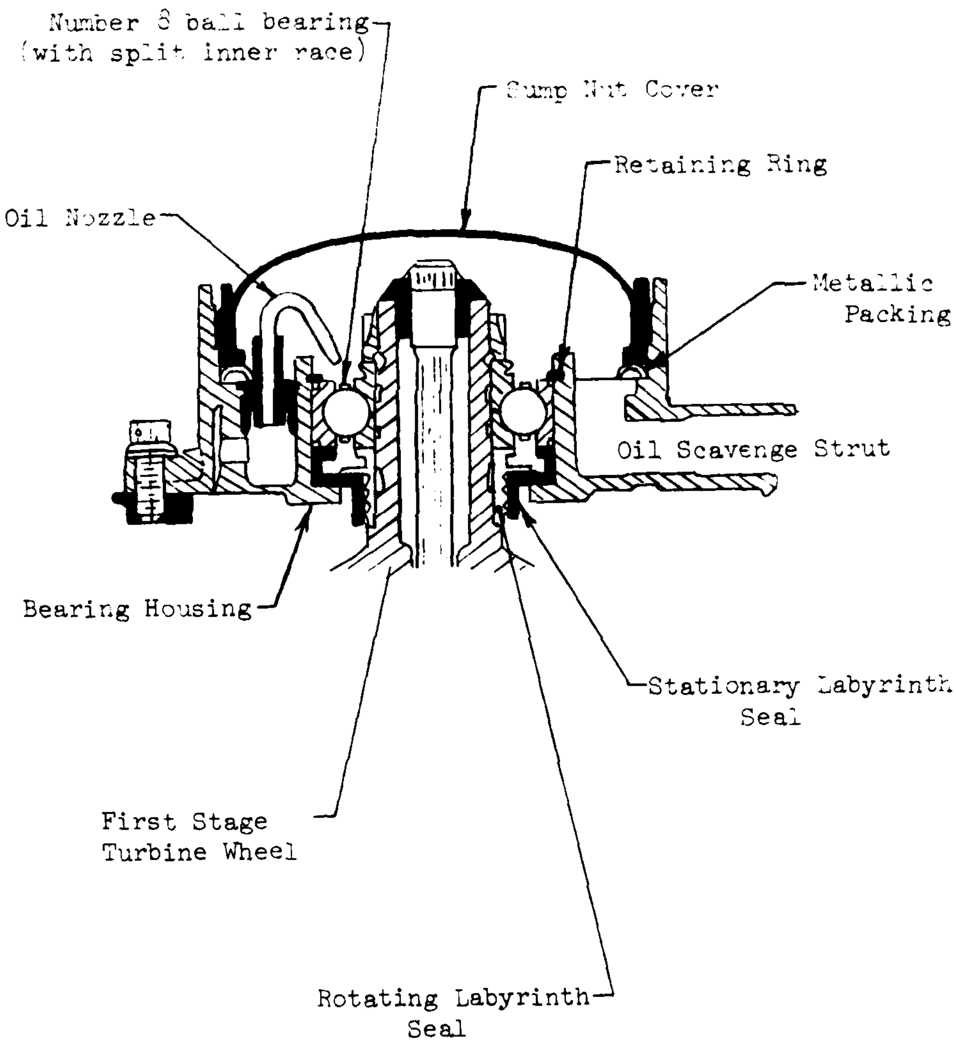
NUMBER 8 BEARING HOUSING, ENGINE

MODEL T63-A-700, STANDARD



NUMBER 8 BEARING HOUSING, ENGINE MODEL

T63-A-5A, STANDARD



APPENDIX C

THERMOCOUPLE INSTALLATION

1. The engines used in Phases II and III of the test program were equipped with three thermocouples in the turbine section. These thermocouples were inserted into the turbine rotor support housing, one in the common number [illegible]-7 bearing compartment and the other two in the number 8 bearing compartment, as shown in enclosures 1 through 3. The thermocouples were used to measure surface temperatures within the engine. They are useful in the comparison of engines to assure that all lubricants are exposed to the same temperature conditions in any of the engines used in the test program.

2. The first thermocouple in the Gas Turbine Support (GTS) component, labeled as Temperature Metal Surface 1 (TMS1), is shown in enclosure (1). This probe gains access through a hollow support strut and is secured to the outer wall of the number 8 bearing housing as shown in enclosure (2). The thermocouple is a skin type, that is, one which is tack-welded to the subject surface. It is located in a static area of the gas path bordered by the stationary GTS and the rotating first stage gas turbine wheel. Orginally, the probe was pressed against the housing surface; however, this style of installation seemed unreliable as the probe could lose surface contact due to engine "growth" and the method was discontinued in favor of the tack-welded installation.

3. The second and third thermocouples were also tack-welded skin type. They were located on the inner wall of the number 7 and number 8 bearing housings as shown in enclosures (2) and (3). These thermocouples were identified as Temperature Bearing 7 (TBR7), and Temperature Bearing 8, (TBR8), and are both on oil-wetted surfaces. To gain entry into their respective bearing compartments, both the TBR7 and TBR8 probes must penetrate a hot air cavity. The cavity was bridged by using a stainless steel tube inserted via a hole drilled into the turbine support, passed down a hollow support strut and through a hole drilled into the bearing compartment wall. The compartment end of the tube was silver soldered to the cavity wall and the other end welded to a tube fitting. The fitting in turn was welded to the outer casing of the turbine support. The installation is depicted in enclosures (2) and (3).

4. Originally both the TBR7 and TBR8 probes were installed somewhat differently. In the first method of instrumentation the bearing compartment end of the stainless steel tube was tapered and pressed into the drilled hole in the bearing compartment. This method worked well for one specific engine. However, when a different engine was utilized, gross leakage occurred at the penetration point into the bearing compartments. This leakage resulted in the modification of the installation by silver soldering the stainless steel tube to the bearing compartment wall, thus insuring positive sealing.

SIGNIFICANCE OF TEMPERATURE MEASUREMENTS

1. Temperature, Metal Surface 1 Probe

a. The TMS1 thermocouple is located in a static gas pocket as seen in enclosure (2). The gas in this static area comes from cooling air which surrounds the aft side of the number 8 bearing support. The air is then directed to the rim of the first stage turbine wheel. Most of the air escapes into the gas path and a small amount fills the pocket. The air in the pocket combined with a labyrinth seal provides a pressure barrier preventing oil leakage from the number 8 bearing compartment. Air flow across the labyrinth seal is normal and replenishment comes from the supply of air directed at the turbine wheel. For a constant power setting the air flow through the chamber is constant which will produce a relatively stable gas temperature at the TMS1 location. Since the TMS1 probe is on a metal surface in the static gas pocket it should also have a fairly constant temperature. Therefore, any change in TMS1 indicates a change in the cooling air within the pocket.

b. The primary component influencing temperature variations in the air pocket of the TMS1 probe is the first stage turbine nozzle. This assembly consists of the first stage turbine vanes and a sheet metal diaphram. It is affixed to the gas producer turbine support with five bolts. The flexible diaphram permits axial and radial growth of the assembly and has several small holes which direct cooling air to the rim of the first stage turbine wheel. A fiberglass rope packing is used to provide sealing between the nozzle and support splitlines. Cooling air leakage through cracks in the diaphram or past the rope packing would cause localized temperature variations in the TMS1 air pocket. The TMS1 probe is appreciably affected by this type of air leakage into the gas path, while the normal leakage of air into the nearby bearing compartment produces little change in the TMS1 value recorded.

2. Temperature, Bearing Number 8 Probe

a. The balance chamber, shown in enclosure (4), is a pressure chamber used to counteract the forces acting on the gas turbine assembly as a result of gas impingement on the turbine blades. The source of balance chamber air is the same as that used for cooling of the first stage wheel. As in the case of the static pocket in the TMS1 location, the gas flow rate in the balance chamber is equal to the small amount of air being delivered to replace the normal leakage across the labyrinth seals. This equilibrium situation will produce a constant gas temperature in the balance chamber for any stabilized power setting. Excessive leakage across the aft seal will however, allow the air to escape into the turbine gas path, thus reducing the effectiveness of the chamber.

b. The balance chamber together with the number 8 ball bearing is responsible for carrying the axial loads of the gas producer turbine assembly. Excessive leakage through its aft seal will reduce the chamber's ability to carry these loads and the extra burden must be picked up by the number 8 bearing. The increased load on the bearing will cause it to operate at a higher temperature (TBR8) than normal and will be evidenced by a reduction in gas turbine rotor speed. Additional changes in TBR8 would be caused by hot air leaking into the bearing compartment through a faulty thermocouple probe penetration, "bad" labyrinth seal or an improperly sealed oil sump cover nut.

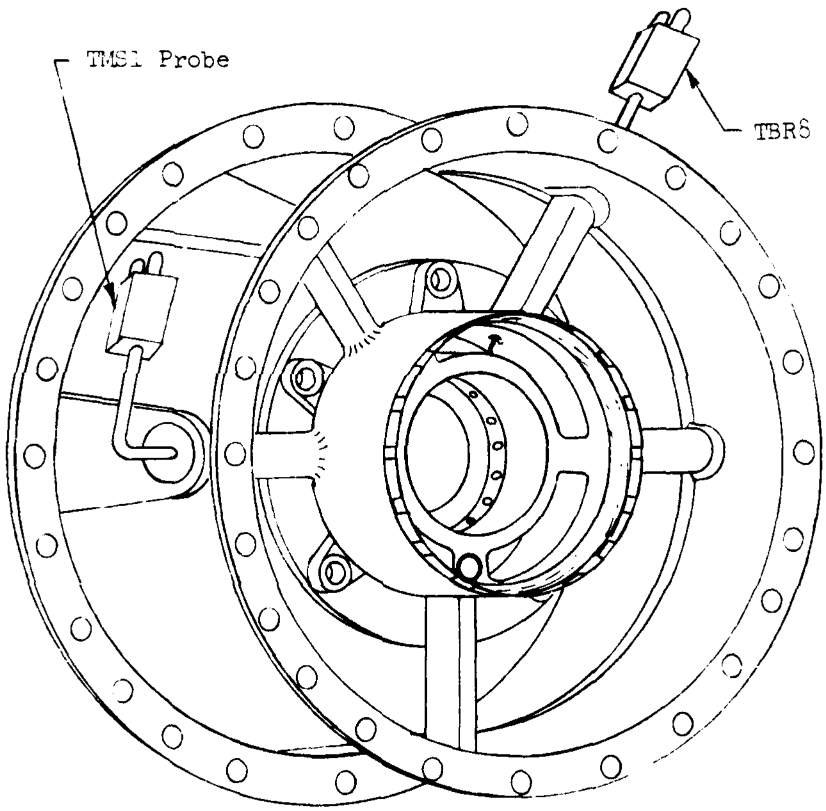
3. Temperature, Bearing Number 7 Probe

The balance chamber is adjacent to the common number 6-7 bearing compartment as shown in enclosure (4). Air leakage through the forward seal of the chamber, in conjunction with a pair of labyrinth seals, is used to provide oil sealing for the number 6-7 bearing compartment. This air leakage through the forward seal is also used to cool the power turbine assembly. Worn labyrinth seals would permit air leakage into the bearing compartment which would cause an increase in the gearbox breather pressure and rise in the TBR7 temperature. If the aft labyrinth seal of the balance chamber is worn, the proper air pressure needed to offset the loading on the gas producer turbine cannot be developed. The insufficient chamber pressure would reduce the amount of cooling air flow through the power turbine assembly and result in an increased TBR7 temperature.

4. Effects of Leakage Into Bearing Compartments

The number 6-7 and 8 bearing compartments in the T63 engine utilize labyrinth seals for oil cavity sealing. Normally a small amount of air passes from the air side of the seal into the bearing compartment. This air exits the compartment with the scavenged oil and is vented into the oil tank or gearbox. If there is excessive air leakage into the compartment due to a worn seal or faulty thermocouple penetration, it will be evidenced by higher than normal gearbox pressure and an increase in temperature within the bearing compartment. This abnormal leakage will also increase oil consumption.

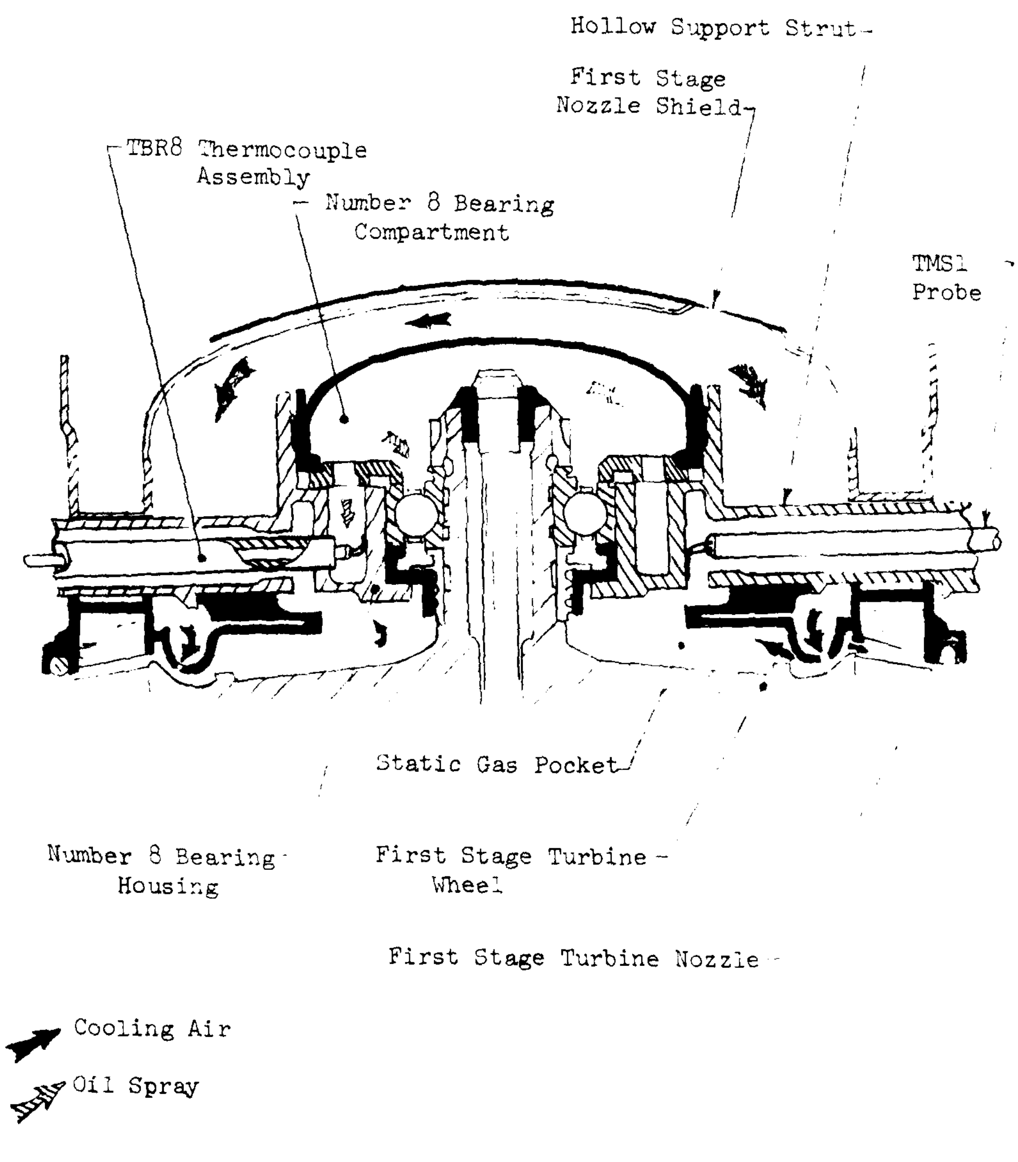
GAS TURBINE SUPPORT THERMOCOUPLE LOCATIONS



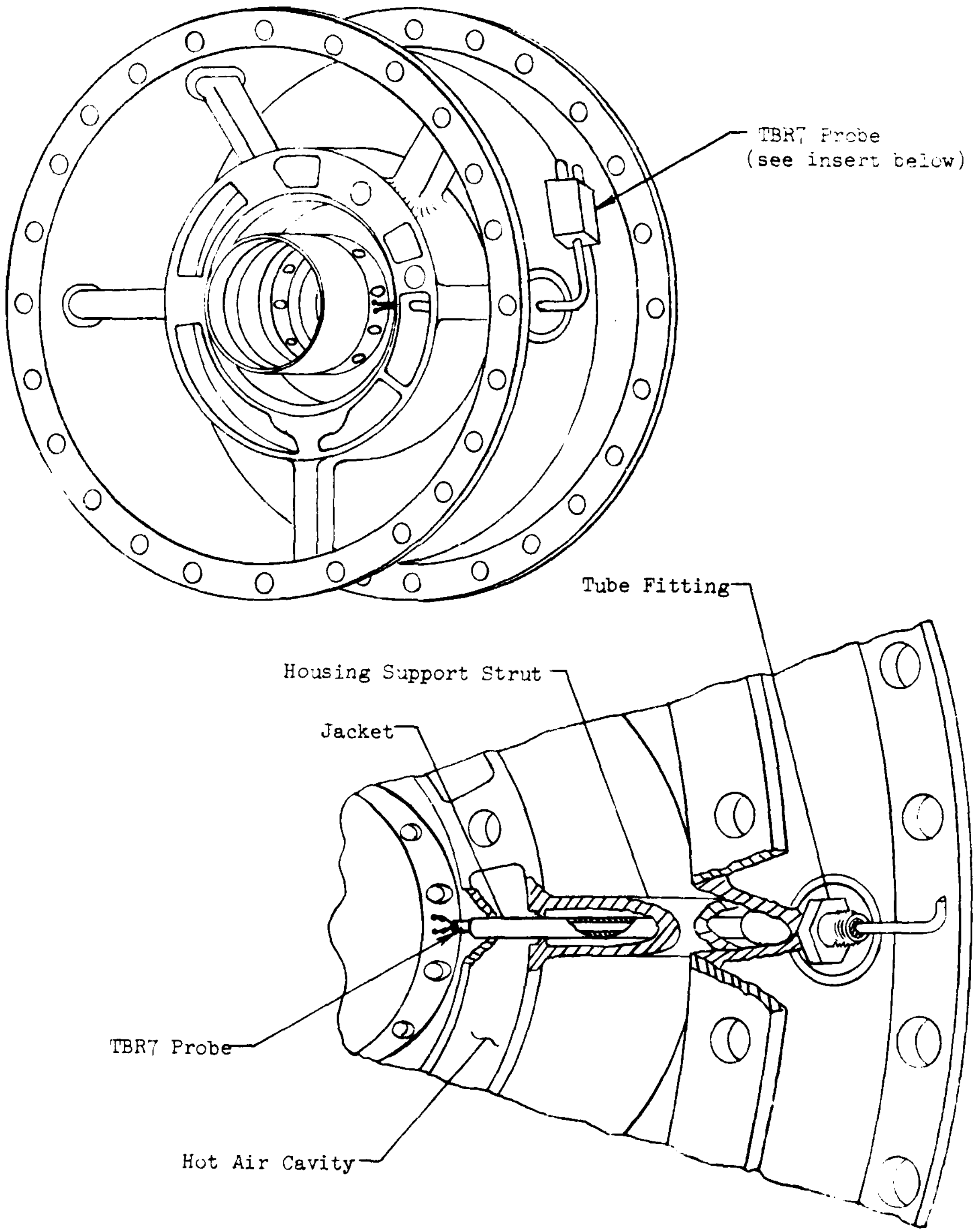
Enclosure (1)

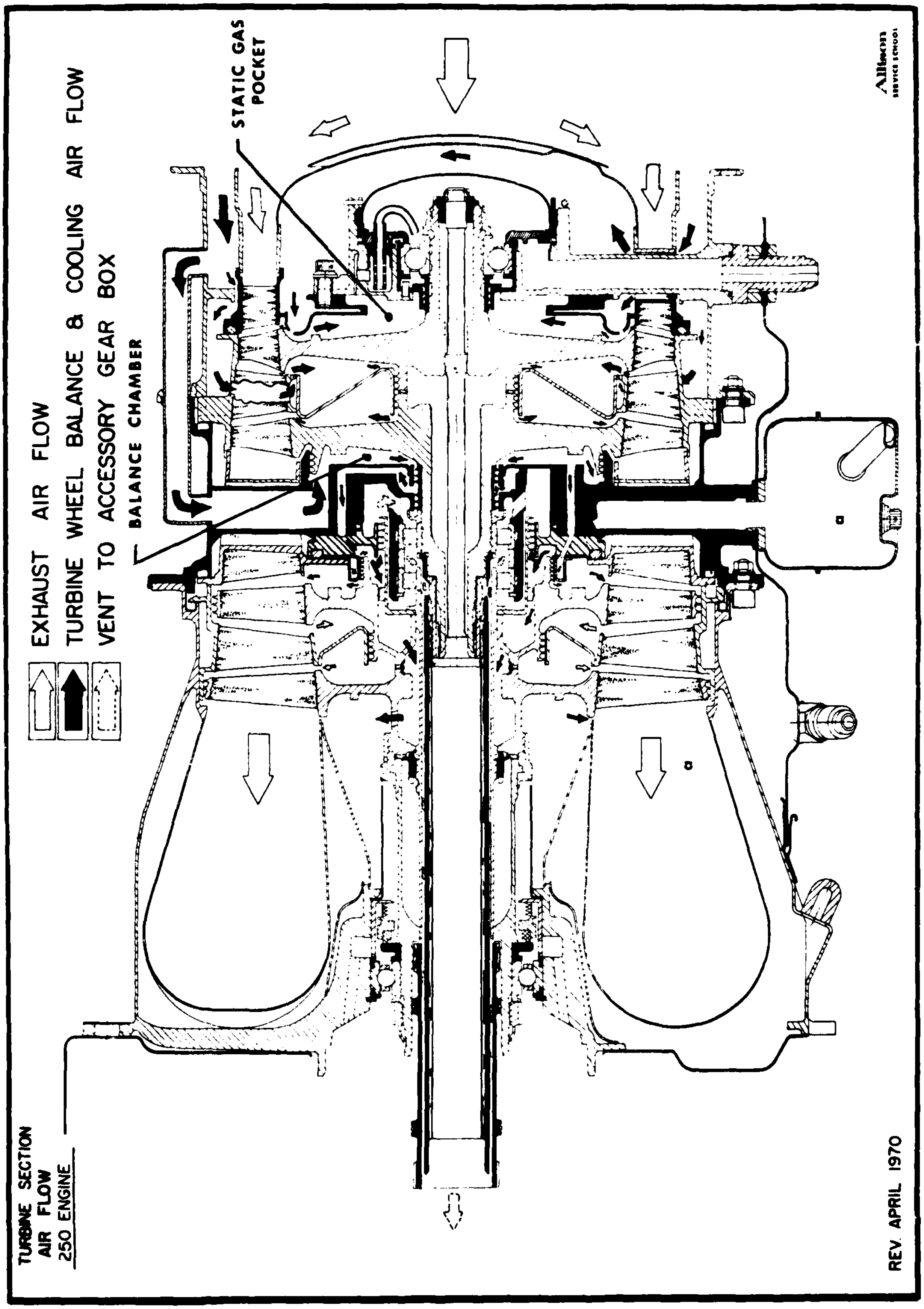
GAS PRODUCER TURBINE SUPPORT ASSEMBLY

WITH NUMBER 8 BEARING INSTALLED



POWER TURBINE SUPPORT THERMOCOUPLE LOCATION/INSTALLATION

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TURBINE WHEEL BALANCE & COOLING AIR FLOW
VENT TO ACCESSORY GEAR BOX
BALANCE CHAMBER
STATIC GAS POCKET
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TURBINE SECTION
AIR FLOW
250 ENGINE
REV. APRIL 1970

APPENDIX D

REPORT ON T63-A-5A TURBOSHAFT ENGINE INSPECTION

Phase III - First Test

Inspected by: P.A.Karpovich
J.T.Shimski

Lubricating Oil: PE-5-L686

Test Equipment: T63-A-5A, S/N W33

		Hours
Operating Time:	1.33 Hour Cycles (110)	146.3
	Miscellaneous	3.7
	Total	150.0

Total Number of Starts/Hot Shutdowns: 115/110

Oil Consumption: 35 ml/hour

Temperatures: Test was run with a "hot" tank. Oil to the Nos. 6-7 and 8 bearing compartments was controlled at 300°F (149°C). Engine oil-in temperature was maintained at 250°F (121°C).

INSPECTION RESULTS

BEARINGS

Power Turbine Rotor Front (No. 5) (Ball)
    Light tan varnish all over

Power Turbine Rotor Rear (No. 6) (Roller)
    Cage - Medium dark varnish to crinkled carbon
    Rollers - Thin black varnish
    Outer Race - Thin black varnish

Gas Turbine Rotor Front (No. 7) (Roller)
    Cage - Thin to medium black varnish
    Rollers - Thin black varnish
    Outer Race - Granular carbon
    Inner Race - Front non-track area medium varnish remainder thin black varnish

Gas Turbine Rotor Rear (No. 8) (Ball)
    Cage - Thin black varnish; heavy pocket wear with some spalls
    Balls - Frosted wear pattern
    Outer Race - Thin black varnish
    Inner Race - Thin varnish

No. 6-7 Bearing Spacer
    Inside - Thin to medium crinkled carbon
    Outside - Thin black varnish

HOUSINGS

Power Turbine Support Sump (No. 6-7 area)
    Thin smooth carbon to black varnish all over; heavy carbon in labyrinth seal cavity

    Scavenge Port - Thin smooth carbon; no restriction in area

    Inlet Port - Light smooth carbon; no restriction in area

Gas Turbine Support Sump (No. 8 area)
    Thin smooth carbon to black varnish all over; some build-up in top pocket; some granular carbon in end cover mating area

    Scavenge Port - Thin smooth carbon all over - scavenge port tube has some light carbon and light sludge on outside

    Inlet Port - Thin smooth carbon all over

    End Cover - Thin smooth carbon all over

    Nut - Thin black varnish

    Screen - Thin black varnish

    Retaining Plate - Thin black varnish and light smooth carbon

SEALS

No. 5 Carbon Seal - Thin smooth carbon; seal free

No. 6-7 Labyrinth Seal - Thin black varnish all over

No. 8 Labyrinth Seal - Light smooth carbon all over

Gearbox Silicone Seals - Good condition; no shrinkage or permanent set

MISCELLANEOUS

Power Turbine Shaft
Interior - Medium crinkled to flaky in tube

Exterior - Some leakage at oil bellows seal; light smooth carbon between seal and #5 bearing

Turbine to Compressor Coupling
Interior - Compressor Side - Thin black sludge
Turbine Side - Light to medium crinkled carbon

Exterior - Compressor Side - Light varnish
Turbine Side - Light to medium black varnish

Turbine to Pinion Gear Coupling Shaft
Interior - Thin black sludge

Exterior - Normal wear on pinion gear; clean with rubbing on end of shaft (#5 side)

External Sump
Light smooth carbon on inside

No. 6-7 Oil Jet
Jet - Clear

No. 8 Supply Tube
Some thin deposits on inside of the tube

No. 8 Oil Jet
Jet - clean
Outside - Thin black varnish

Main Oil Pump
Gears - Good condition
Screen - Usual debris between pleats
Screen Housing - Some thin sludge in pockets

APPENDIX E

REPORT ON T63-A-5A TURBOSHAFT ENGINE INSPECTION

Phase III - Second Test

Inspected by: P.A.Karpovich
J.T.Shimski

Lubricating Oil: AED-5-L296

Test Equipment: T63-A-5A, S/N 401331

		Hours
Operating Time:	1.33 Hour Cycles (130)	171.0
	Miscellaneous	4.0
	Total	175.0

Total Number of Starts/Hot Shutdowns: 140/130

Oil Consumption: 45 ml/hour

Temperatures: Test was run with a "cold" tank. Oil to the Nos. 6-7 and 8 bearing compartments was controlled at 300°F (149°C). Engine oil-in temperature was maintained at 250°F (121°C).

INSPECTION RESULTS

BEARINGS

Front Compressor Bearing (No. 1) (Ball)
Clean; rough running

Rear Compressor Bearing (No. 2) (Ball)
Light tan varnish; good condition

Front Power Train Pinion Bearing (No. 3) (Ball)
Good condition

Rear Power Train Pinion Bearing (No. 4) (Ball)
Light tan varnish all over

Power Turbine Rotor Front (No. 5) (Ball)
Light tan varnish all over

Power Turbine Rotor Rear (No. 6) (Roller)
Cage - Medium dark varnish to medium crinkled carbon
Rollers - Thin black varnish
Outer Race - Thin black varnish

Gas Turbine Rotor Front (No. 7) (Roller)
Cage - Medium black varnish and crinkled carbon
Rollers - Thin black varnish
Outer Race - Thin black varnish
Inner Race - Front non-track area medium varnish
- Track area; thin black varnish

Gas Turbine Rotor Rear (No. 8) (Ball)
Cage - Thin black varnish; heavy pocket wear
Balls - Frosted wear pattern
Outer Race - Thin black varnish
Inner Race - Thin black varnish with some carbon

No. 6-7 Bearing Spacer
Inside - Thin to medium crinkled carbon
Outside - Thin black varnish

HOUSINGS

Power Turbine Support Sump (No. 6-7 area)
Thin smooth to crinkled carbon and black varnish all over - Medium carbon in labyrinth seal cavity

Scavenge Port - Thin smooth to crinkled carbon

Inlet Port - Light smooth carbon; some restriction in area midway through strut

Gas Turbine Support Sump (No. 8 area)
    Thin smooth carbon to black varnish all over, some build-up in top pocket

    Scavenge Port - Thin smooth carbon all over

    Inlet Port - Thin smooth carbon all over

    End Cover - Thin smooth carbon all over

    Nut - Thin black varnish

    Screen - Thin smooth carbon with thin black varnish

    Retaining Plate - Thin black varnish with some light smooth carbon

SEALS

No. 1 Carbon Seal - Clean

No. 5 Carbon Seal - Heavy smooth carbon on oil side; seal free

No. 6-7 Labyrinth Seal - Carbon in seal grooves

No. 8 Labyrinth Seal - Smooth carbon all over; some build-up behind wheel

Gearbox Silicone Seals - Good condition; no shrinkage or permanent set

MISCELLANEOUS

Power Turbine Shaft
    Interior - Medium to heavy crinkled to flaky carbon

    Exterior - Very light smooth carbon between seal and No. 5 bearing

Turbine to Compressor Couplings
    Interior - Compressor side - Thin black sludge and granular carbon
             - Turbine side - Medium crinkled carbon

    Exterior - Compressor side - Some very light varnish
             - Turbine side - Light to medium black varnish; some peeling

Turbine to Pinion Gear Coupling Shaft
    Interior - Turbine side - Thin crinkled carbon
             - Gearbox side - Thin black sludge with some granular carbon

    Exterior - Normal wear on pinion gear; very light smooth carbon on shaft

Power Turbine Pinion Gear
    Thin black oily sludge on inside; normal wear on teeth

External Sump
    Some build-up of carbon on top at inlet port
    Light smooth carbon all over
    (Note: condition of sump prior to testing unknown)

No. 6-7 Oil Jet
Jet - Clear
Exterior - Thin to medium smooth carbon

No. 6-7 Crossover Tube
Clear

No. 8 Supply Tube
Thin black sludge on outside of tube

No. 8 Oil Jet
Jet clear; thin black varnish on outside

Main Oil Pump
Gears - Good condition
Screen - Usual debris between pleats
Screen Housing - Some granular carbon and metal chips

APPENDIX F

REPORT ON T63-A-5A TURBOSHAFT ENGINE INSPECTION

Phase III - Third Test

Inspected by: P.A.Karpovich
J.T.Shimski

Lubricating Oil: PE-5-L743

Test Equipment: T63-A-5A, S/N W-58

		Hours
Operating Time:	1.33 Hour Cycles (131)	174.23
	Miscellaneous	1.0
	Total	175.23

Total Number of Starts/Hot Shutdowns: 134/131

Oil Consumption: 18.0 ml/hour

Temperatures: Test was run with a "cold" tank. Oil to the Nos. 6-7 and 8 bearing compartments was controlled at 300°F (149°C). Engine oil-in temperature was maintained at 250°F (121°C).

INSPECTION RESULTS

BEARINGS

Front Compressor Bearing (No. 1) (Ball)
Good condition, clean

Rear Compressor Bearing (No. 2) (Ball)
Good condition, clean

Front Power Train Pinion Bearing (No. 3) (Ball)
Good condition, clean

Rear Power Train Pinion Bearing (No. 4) (Ball)
Good condition, clean

Power Turbine Rotor Front (No. 5) (Ball)
Light tan varnish, good condition

Power Turbine Rotor Rear (No. 6) (Roller)
Cage - Light black varnish
Rollers - Light black varnish
Outer Race - Light black varnish

Gas Turbine Rotor Front (No. 7) (Roller)
Cage - Light black varnish (aft), light to medium black varnish (forward side)
Rollers - Thin black varnish
Outer Race - Thin black varnish
Inner Race - Front non-track area thin black varnish
- Track area; thin black varnish

Gas Turbine Rotor Rear (No. 8) (Ball)
Cage - Thin black varnish
Balls - Thin black varnish
Outer Race - Thin black varnish
Inner Race - Thin black varnish

No. 6-7 Bearing Spacer
Inside - Light smooth carbon
Outside - Thin black varnish, light smooth carbon

HOUSINGS

Power Turbine Support Sump (No. 6-7 area)

Light smooth carbon to thin black varnish all over - Labyrinth seal cavity - thin carbon

Scavenge Port - Thin smooth carbon with no restriction in area

Inlet Port - Thin smooth carbon - no restriction in area

Gas Turbine Support Sump (No. 8 area)

Thin black varnish all over with thin smooth carbon in pocket areas

Scavenge Port - Clean

Inlet Port - Thin tan varnish

End Cover - Very thin smooth carbon to tan varnish all over

Nut - Thin black varnish

Screen - Black varnish, screen clean

Retaining Plate - Very light smooth carbon to thin black varnish all over

SEALS

No. 1 Carbon Seal - Clean, good condition

No. 5 Carbon Seal - Clean, good condition

No. 6-7 Labyrinth Seal - Very little carbon in seal grooves

No. 8 Labyrinth Seal - Thin black varnish all over

Gearbox Silicone Seals - Good condition, no shrinkage or permanent set

MISCELLANEOUS

Power Turbine Shaft
Interior - Thin to medium crinkled carbon

Exterior - Thin black varnish between seal and No. 5 bearing

Turbine to Compressor Coupling
Interior - Compressor side - very thin black sludge
Turbine side - light granular carbon

Exterior - Compressor side - clean
Turbine side - light black varnish

Turbine to Pinion Gear Coupling Shaft
Interior - Turbine side - thin black sludge
- Gearbox side - thin black sludge with some granular carbon

Exterior - Normal wear on pinion gear; light black varnish on shaft

Power Turbine Pinion Gear
Thin black oily sludge on inside; normal wear on teeth

External Sump
Thin smooth carbon above oil line; below oil line clean

No. 6-7 Oil Jet
Jet - Clear
Exterior - thin smooth carbon and black varnish

Crossover Tube
Clear

No. 8 Supply Tube
Clean

No. 8 Oil Jet
Jet clear; light smooth carbon on outside

Main Oil Pump
Gears - good condition
Screen - less than normal amount of debris between pleats
Screen Housing - clean

Gearbox
Good condition

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